Outcomes after Hernioplasty Utilising Low Cost Mesh in Low and Middle Income Countries: A Systematic Review

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Clinical Science

Dr Ashish Immanuel Vaska
MBBS, BMedSci(Hons)

Joanna Briggs Institute
Faculty of Health and Medical Sciences
University of Adelaide

December 2020

Table of Contents

Summary

Inguinal hernias are a source of significant morbidity and mortality in low and middle income countries (LMICs). Best practice for inguinal hernia repair (IHR) is hernioplasty but the cost of surgical mesh required limits its use in LMICs. Clinicians in LMICs have attempted to increase access to hernioplasty by seeking out cheaper alternatives to surgical mesh. Low cost mesh (LCM) includes mosquito netting, resterilised surgical mesh and other indigenous products. The use of LCM in inguinal hernioplasty in LMICs has been well described in the literature and two recent limited systematic reviews of mosquito net hernioplasty found equivalent postoperative surgical outcomes. The objective of this review was to build on extant reviews by conducting a broader search across a wider set of databases and grey literature sources, including all LCM alternatives and considering outcomes such as patient and surgeon preference, sterility and recurrence alongside a more granular assessment of complication rates. The review aimed to assist clinicians in LMICs in their decision-making regarding use of LCM, in particular, identifying potential areas for improvement of practice with regards to sterility and mesh choice.

Electronic bibliographic databases, grey literature databases and trial registers were searched for randomised or quasi-randomised controlled trials, comparing surgical mesh vs low cost mesh in adult patients undergoing elective inguinal hernioplasty or emergent inguinal hernioplasty without bowel resection in LMICs, published in any language from 2000 to present date.

Two independent reviewers conducted the literature search, title/abstract and full text screening, assessed methodological quality using the Cochrane Risk of Bias 2 tool and extracted data using a custom extraction tool. Synthesis involved pooling for statistical meta-analysis with either random-effects or fixed-effects model as appropriate, and where this was not possible, a narrative presentation of findings was reported.

11 RCTs with 1306 participants were identified. There was little to no evidence of an effect for low cost mesh vs surgical mesh on the assessed outcomes: recurrence RR 1.44 (95CI: 0.23 to 9.04, low certainty), chronic pain RR 0.68 (95CI: 0.24 to 1.92, low certainty), superficial infection RR 0.84 (95CI: 0.46 to 1.54, low certainty), deep infection (95CI: 0.12 to

71.15, very low certainty), explantation RR 2.93 (95CI: 0.31 to 27.71, very low certainty), seroma RR 1.06 (95CI: 0.53 to 2.11, moderate certainty), haematoma RR 1.01 (95CI: 0.69 to 1.49, moderate certainty), postoperative pain MD 0.07 lower (95CI: 0.27 lower to 0.14 higher, high certainty).

The use of LCM in hernioplasty in LMICs delivers outcomes that are not significantly different to hernioplasty with surgical mesh. This systematic review identified that for the best assessed outcomes of chronic pain, superficial and deep infection rates, seroma and haematoma formation, mesh explantation and hernia recurrence, there was no significant difference in outcomes between surgical mesh and LCM. Based on this review, the use of LCM in hernioplasty in LMICs can be recommended as a safe alternative, with the caveats of satisfactory sterilisation and adequately trained service providers.

Acknowledgements

To my supervisors, Associate Professor Zachary Munn, Dr Timothy Barker and Dr Sonal Nagra, my sincere thanks for your support, input and feedback during the development and conduct of this review. Thank you for your encouragement and enthusiasm over the duration of my candidature.

To my co-reviewer, Dr Jack Jiao, thank you for your assistance in screening, appraising and data extraction.

To Jorge Salavert, thank you for your assistance in translation for identified studies.

To the JBI staff, in particular, Alex Mignone, thank you for all your help in navigating the requirements of this degree. I would also like to thank the research librarians at the University of Adelaide for their suggestions regarding my search constructions.

To my family and friends, thank you for your forbearance with me and encouragement to continue pressing on. I greatly appreciate your patience with me over the past few years and for allowing me to air and test ideas and thoughts with you.

Declaration of Originality

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I acknowledge that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

Ashish Immanuel Vaska

16 December 2020

List of figures

List of tables

List of appendices

List of abbreviations

AAS – Activities Assessment Scale

ASA – American Society of Anaesthesiologists Physical Status score

BMI – body mass index

CCS – Carolinas Comfort Scale

CDC – Centers for Disease Control

CONSORT – Consolidated Standards for Reporting Trials

CPIP – chronic post inguinal herniorrhaphy pain

DSSI – deep surgical site infection

ETO – ethylene oxide

GA – general anaesthesia

GRADE – Grading of Recommendations, Assessment, Development and Evaluations

HIC – high income country

HICs – high income countries

LMIC – low and middle income country

LMICs – low and middle income countries

PP – polypropylene

PE – polyethylene

LDPE – low density polyethylene

HDPE – high density polyethylene

IH – inguinal hernia

IHR – inguinal hernia repair

IPQ – Inguinal Pain Questionnaire

JBI – Joanna Briggs Institute

LA – local anaesthesia

LCM – low cost mesh

MD – mean difference

OLQUI – Ouagadougou Life Quality Index

PHS – Prolene Hernia System

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-analyses

PRO – patient reported outcome

PROM – patient reported outcome measure(s)

QOL – quality of life

RCT – randomised controlled trial

RoB2 – Risk of Bias 2

RR – relative risk

SF36 – 36-item Short Form Health Survey

SSI – surgical site infection

SSSI – superficial surgical site infection

VAS – visual analogue score / visual analogue scale

WHO – World Health Organisation

Chapter 1: Introduction

Hernia definition

Abdominal wall hernias are a protrusion of the abdominal contents, typically bowel or fat, through a muscular or fascial defect.[1] The most common abdominal wall hernias are groin hernias, that is, inguinal or femoral hernias and inguinal hernias are more common.[2-4] Inguinal hernias can be further subdivided into indirect or direct inguinal hernias. While these subtypes exist in close proximity and can be difficult to distinguish clinically, they have differing anatomy and aetiologies.[2] Indirect inguinal hernias are a congenital defect resulting from the failure of obliteration of the processus vaginalis during embryonic development with the hernia arising lateral to the inferior epigastric vessels.[2,5] Direct inguinal hernias are an acquired defect with weakening of the posterior wall of the inguinal canal medial to the inferior epigastric vessels, within the space bounded by Hasselbach's triangle.[3,5] This space is bordered by the inferior epigastric vessels laterally, the lateral border of the rectus abdominis muscle medially and the inguinal ligament inferiorly.[2,5] Other described inguinal hernias include pantaloon hernias with both indirect and direct components and sliding hernias, an acquired hernia where retroperitoneal fat or visceral organs comprise part of the wall of the hernia sac.[2,3,6]

Natural history of inguinal hernia

Inguinal hernias were described in the Ebers Papyrus circa 1550 BC[7] and treatment of hernias was recorded by Hammurabi of Babylon in 1700 BC.[8] However, the natural history of inguinal hernias is still not well understood.[9,10] Broadly, it includes development of pain, increasing size, irreducibility and hernia complications, although these may not occur in a linear progression. Pain may be a direct result of the hernia causing pressure symptoms or neural irritation or be a consequence of intermittent obstruction. Progressive increase in hernia size may result in the development of inguinoscrotal hernia or cause changes in the overlying skin such as ulceration. Irreducibility is an inability for hernia contents to be returned into the abdominal cavity[11] and is related to both the size of the hernial sac and the hernia orifice. Irreducible hernias may also be described as incarcerated hernias.[2] Hernia

complications are rare but can have serious consequences.[10] Bowel obstruction occurs when the passage of enteric content is prevented by mechanical constriction of the bowel within the hernia sac. Strangulation is the vascular compromise of hernia sac contents.[11] When a hernia containing bowel becomes strangulated, progressive ischaemia results in compromise of mural integrity, bacterial translocation and bowel perforation with a significant risk of sepsis and mortality.[12] In a mechanical bowel obstruction, vascular compromise will develop over time secondary to mural oedema and eventually perforation may occur.

Historical surgical practice was to repair all inguinal hernias including asymptomatic hernias, on the basis that repair was safe and averted the risk of hernia complications.[12] Repairs were initially performed as tissue only repairs and later with use of implanted mesh products to provide a tension-free repair.[13] Annually, 20 million inguinal hernia repairs are now performed worldwide.[14] Given this significant number of surgeries, the costs associated with operating are large as is the potential for overtreatment. Investigation into complications post-hernioplasty have found higher rates of operative complication than was initially estimated, particularly chronic postoperative inguinal pain (CPIP) although this does reduce over time.[12,15]

The role for watchful waiting in particular patient subgroups has been investigated and found to be safe in asymptomatic or minimally symptomatic patients[15,16], although there is a high rate of progression to operation.[10,17,18] A review of the literature conducted in 2018 by the HerniaSurge group concluded that it was not possible to determine the hernia complication rate in symptomatic hernias. Consequently, the safety of a watchful waiting strategy in symptomatic patients was not assessable.[12] HerniaSurge recommend surgical treatment for symptomatic patients and individual decision making for asymptomatic or minimally symptomatic patients.[12] The recommendation for individual decision making is made on the basis of low complication risk and consideration of patient age, preferences and comorbidities and acknowledges that most patients will develop symptoms necessitating repair.[12]

Hernia repair techniques

The principles of hernia repair are identification of the hernia sac and dissection of its neck, reduction of sac contents and repair of the fascial defect.[19] Repair of the fascial defect can utilise the surrounding tissues and is known as herniorrhaphy.[11] Repair can also be performed using a synthetic mesh product to bridge the fascial defect, providing a tension-free repair, and is known as hernioplasty.[11]

Anatomically, hernia repair can occur in various different planes and approaches. Operative approaches can be divided into anterior and posterior. The anterior approach involves incision through the external oblique aponeurosis and accessing the inguinal canal and the posterior approach involves entry into the preperitoneal space behind the inguinal canal.[5] Placement of mesh during hernioplasty varies. Mesh can be sited in an onlay position, sitting against the posterior wall of the inguinal canal or in a sublay or preperitoneal position, behind the inguinal canal and above the peritoneum.[20]

Hernia repair was revolutionised by Bassini in 1887 and his described technique for reconstruction of the posterior wall of the inguinal canal forms the basis for modern inguinal hernia repairs.[7,14] This was followed by the development of numerous other tissue-based repairs including the McVay and Shouldice methods.[8] Lichtenstein's tension-free repair ushered in the routine use of mesh in inguinal hernia repair and is now the current gold standard for open inguinal hernia repair.[12,14,21]

Mesh repairs have been demonstrated to have lower recurrence rates than tissue repairs.[22,23] However, the quality of studies included in the Cochrane review comparing non-mesh vs mesh repairs was deemed to be low.[24,25] The Lichtenstein onlay repair has been the most well studied in the literature and is widely used due to its reliability, cost-effectiveness, relatively flat learning curve and the ability for reproducible results across the spectrum of expertise.[12,14] It is associated with low rates of recurrence[22,24,25], shorter operating time[22,24], faster postoperative recovery[22] and return to work[22] and reduced postoperative pain when compared with tissue based repairs.[22] There is no evidence to support higher rates of chronic pain in mesh based repairs.[12] The Amid update of the Lichtenstein repair

recommended the use of a 7cm by 16cm mesh to provide 2cm medial, 3-4cm superior and 5-6cm lateral coverage across the inguinal floor.[26] This modification aimed to reduce recurrence, nerve entrapment and ensure the repair remained tension-free under movement.[26] This mesh sizing is the standard used in Lichtenstein repair.[2,3]

Complications of hernioplasty

Complications of hernioplasty can be procedural or construct related. Procedural complications include infection, seroma, haematoma, pain, postoperative neuralgia, testicular injury including pain, orchitis and atrophy, sexual dysfunction, recurrence and mesh explantation, which is typically due to chronic pain, hernia recurrence or mesh migration.[11,13] Chronic pain is the most common complication.[11] Population studies estimate that one third of all patients have pain one year after repair, 50% of whom experience limitation in their daily activities[13,27,28] and severe pain in 1-3%.[12,13] Rarer complications include damage to surrounding organs, vascular injury and mortality.[11,29]

While most hernia repair complications are procedural, some are construct related. The limitations and confounders of clinical studies, including small sample sizes, make it challenging to compare materials and their outcomes.[12] Complications directly related to the mesh construct include shrinkage[30], migration[31] and degradation.[12,32] Complications associated with or induced by the presence of mesh include deep infection[33], fistula formation, adhesion, erosion, chronic pain[34] and limitation of mobility.[35-37]

Hernia mesh

Mesh has been widely used in hernioplasty but due to the incidence of complications, particularly chronic pain, the appropriateness of mesh use in some patient populations has been questioned.[12] Patient concerns about mesh implants stemming from the significant issues with trans-vaginal tape also impact on decision making, with some patients refusing its use.[38] However, mesh used in inguinal hernia repair has been extensively investigated for physico-chemical properties and safety and is used in a fundamentally different manner.[38]

History of mesh

Historically, meshes were constructed from a number of different materials. These ranged from silver wire in 1894, tantalum gauze in the 1940s, stainless steel in the 1950s and nylon and Teflon in the mid to late 20th century.[13] Plastic meshes are thermoplastic polymers that were developed in the 1930s and can be moulded, extruded and cast into objects, films or filaments.[13] They now form the majority of mesh implants and include polyester mesh (Dacron®, Mersilene®) commonly used in vascular surgery, polytetrafluoroethylene (PTFE) and polypropylene. Recent advances also include the development of combined biosynthetic or biological meshes, which include substrates that integrate with tissues over time, such as Gore® Bio-A®.[39]

Characteristics of ideal mesh

The ideal qualities of a mesh for use in hernioplasty are the ability to conform to a certain structure and stability profile, sufficient strength to reinforce the repair, ability to stretch, elasticity, ability to integrate into tissues without forming dense scar, low risk of precipitating chronic inflammation and low risk of bacterial adherence.[12,40,41] Biocompatibility increases with low weight, large pore size and monofilament construction but no mesh is inert.[13,40,41] The mesh should have filaments of minimal diameter with sufficient bursting strength, a knit pattern to facilitate maximum porosity and drive tissue ingrowth and have uni- and bidirectional strength.[13] Medical grade production of mesh minimises catalyst and additive use, reducing the potential for foreign body reaction.[13]

Commercial hernia mesh products

Polypropylene is the gold standard mesh for use in inguinal hernia repair.[13] It is a monofilament with excellent infection resistance, heat resistant to 168 degrees Centigrade, has high tensile strength, good flexibility and is biocompatible.[41] Additionally, it can be produced in various gauges and deniers.[13]

Polyester mesh was developed in 1939 and can be produced with either mono- or multifilament fibres.[13] It is not as widely used as polypropylene due to concerns around lower tissue integration, low quality evidence of higher infection rates and equivocal data

around degradation.[13,41,42] It does however have a lower adhesion risk than polypropylene.[13]

Polyethylene, either high density (HDPE) or low density (LDPE), typically has non-general surgical applications, such as porous HDPE in neurosurgical, maxillofacial or plastic surgery and ultra-high molecular weight polyethylene in orthopaedic implants.[43,44] It is also commonly used in non-medical settings, such as in pipes and netting. Polyethylene was developed by Fawcett and Gibson in 1935 and is a semi-crystalline polymer, with amorphous and crystalline regions; the size and distribution of crystalline regions determine the density of polyethylene.[45] HDPE is stronger than LDPE but less flexible.[45]

There are a number of different mesh constructions used in hernioplasty. These include flat mesh, bilayer products and the plug and patch device. Flat mesh products include those with bioabsorbable components and others with microscopic barbs that facilitate fixation without sutures. Bilayer devices, such as the Prolene Hernia System® (PHS), consist of anterior and posterior leaflets connected by a central bridge. Plug and patch constructs comprise conical and flat mesh components. Bilayer and plug and patch products both provide preperitoneal and onlay coverage.

Meta-analyses of randomised controlled trials (RCTs) demonstrated similar long term outcomes for plug and patch vs Lichtenstein repair[46,47] and for PHS vs Lichtenstein repair.[47,48] The HerniaSurge guidelines recommend against PHS and plug and patch repairs in treatment of primary inguinal hernias, despite acceptable and equivalent outcomes to Lichtenstein repair.[12] This recommendation is made due to entry into both anterior and posterior compartments and subsequent limitation of treatment options for recurrence, implantation of a greater quantity of mesh with risk of plug migration and erosion, increased cost and lack of standardised positioning of the devices in the setting of pantaloon hernia.[12]

The HerniaSurge guidelines also recommend use of standard flat mesh over newer self-gripping meshes such as Progrip© mesh. This is made on the basis of similar outcomes

regarding recurrence rates, acute and chronic pain and the increased cost of self-gripping mesh.[12,49]

Hernia mesh properties

Filament structure

Infection risk of mesh is related to filament structure.[50,51] The increased surface area of multifilament mesh and the presence of niches in the multifilament strands facilitate the formation of biofilms and harbouring of bacteria.[33,50] Monofilament meshes are recommended by the HerniaSurge guidelines due to lower infection risk compared with multifilament meshes.[12,33]

Pore size

Pore size is associated with risk of infection[51] and seroma.[13] Amid defined meshes as either macroporous (pore size > 75micron) or microporous (pore size < 10micron) with microporous meshes having higher infection risk.[12,13,52] However, this definition preceded the development of modern hernia meshes which routinely have pore size > 75micron and can now have pore size > 3mm.[30,53] A newer classification of porosity is based on textile porosity, a percentage measurement of the total area of the mesh not covered by filaments.[30] Regardless, the relationship between infection risk and pore size is related by the ability of immune cells to penetrate the mesh[52], the degree of biofilm that develops[33,51] and the extent of foreign body reaction that occurs.[35] Bridging scar formation is also associated with pore size, with smaller pore size increasing the likelihood of scar that occludes the pore completely.[35] This results in a dense scar which can cause pain and reduce mobility.[35]

Weight

Weight of mesh, either lightweight or heavyweight, has been used to describe and classify mesh throughout the literature. However, there has been no consensus regarding the exact definition or classification of these terms.[12,54] In general, the terms represent the historical development of mesh products based on understandings of mesh function and hernia pathophysiology. The HerniaSurge guidelines recommend against classification of mesh by

weight.[12] This is in recognition of the many other properties of mesh that impact on outcomes and the recent biomechanical engineering advances that have led to products that include characteristics of both lightweight and heavyweight mesh.[12]

Heavyweight meshes (HWMs) were developed earlier and aimed to provide strength to the repair with dense mesh constructs and induction of fibrosis via a significant foreign body reaction to bridge the fascial defect.[37,54] Typically, they have thicker polymer fibres[37], smaller pore size and higher tensile strength[54,55] than lightweight meshes.[40] Due to the increased amount of mesh material present, a greater foreign body reaction is provoked with more scar tissue formation and greater mesh shrinkage.[54] This results in chronic pain, foreign body sensation and limitation of mobility.[37,54]

Lightweight meshes (LWMs) were developed later and aimed to approximate abdominal wall function more closely.[37] These constructs usually have thinner polymer fibres, larger pore size and consequently, less material density.[37,40,54] Lightweight meshes induce a lesser foreign body reaction and are more flexible.[37,40,54] Concerns regarding higher recurrence rates with LWMs were raised at their introduction but have not been demonstrated in multiple systematic reviews and meta-analyses.[34,56] Data regarding reduction in pain using LWM in open repairs is mixed, with meta-analyses finding reduced pain with LWM in the early postoperative period[56,57] but randomised trials demonstrating no difference at 5 years between LWM and HWM.[58,59]

Strength

Mechanically, most meshes demonstrate anisotropy, with different mechanical properties when stressed vertically or horizontally, that is, with or against the weave.[12] Older heavyweight meshes were over-engineered with tensile strengths far greater than required for normal activities.[41] The current consensus for the upper limit of strength requirement has been found to be 16N/cm^2 in small hernias and 32N/cm^2 in large hernias where the fascia is widely separated.[37] However, the lower limit is unclear and the majority of surgical products test at or above 16N/cm^2.[60]

Foreign body reaction

Biocompatibility with mesh has also been investigated significantly, given that all meshes induce a foreign body reaction.[61] The extent of the foreign body reaction is related to total amount of implant and inversely related to pore size.[27] As meshes are intended to remain in situ for the life of the patient, toxicological concerns related to the mesh material or production process are compounded over time.[62] Hernia meshes produced for surgical use are physically and chemically inert, non-immunogenic and non-toxic.[63] Animal models have demonstrated mesh-related malignancy secondary to foreign body induced chronic inflammation.[64] However, there is no evidence of malignancy in humans recorded in the literature.[13]

Hernia mesh classification systems

Classification of mesh is complex due to changing and poorly defined terminology. Various systems have been developed based on characteristics of mesh, including mesh weight, pore size, construct material and historical development. Of these, pore size was been identified as a key contributor to biocompatibility and was used in the development of the first classification system by Amid.[30,52] Amid grouped meshes into 4 categories: totally macroporous meshes with pore size > 75micron, totally microporous with pore size < 10micron, macroporous with microporous or multifilamentous components, and biomaterials with submicronic pores.[52] In light of the significant developments in mesh technology, Klinge and Klosterhalfen proposed an updated classification system of 6 mesh categories: large pores with textile porosity > 60%, small pores with textile porosity less than 60%, additional features, without pores, 3-dimensional constructs and biologicals.[30] The absence of a robust classification system for mesh constructs reflects the diversity of products available. This has contributed to difficulties in direct comparison of one mesh against another in the clinical context.

Hernia classification systems

Classification systems for inguinal hernias are numerous and used with varying frequency in clinical practice.[8] Many of these were developed by notable hernia surgeons including McVay, Lichtenstein, Gilbert, Nyhus, Schumpelik (Aachen classification), Stoppa, BenDavid

and Kingsnorth. The Nyhus and Aachen systems are used in practice more frequently, with Nyhus used in both the USA and Europe whereas Aachen is predominantly used in Europe.[65] The need for a classification system that encompassed the variability and complexities of groin hernias, from both laparoscopic and open approaches, and was memorable and simple enough for use in daily surgical practice drove the development of the European Hernia Society Groin Hernia classification system.[66] Uptake of this classification system is not universal and the lack of a universal system raises challenges for comparison of outcomes in clinical studies.

Epidemiology of hernias in low and middle income and high income countries

Globally, inguinal hernia repair is among the most common general surgical procedures performed. It has been estimated that more than 20 million procedures are performed annually.[67] Risk factors strongly associated with development of inguinal hernia include male gender[68], increasing age[68], altered collagen metabolism and those with lower evidence include inherited connective tissue disorders, Caucasian race and socio-occupational factors.[12] The lifetime risk of inguinal hernia repair for men is 27-43% and 3-6% in women.[12,69] Surgical repair is the only treatment for symptomatic hernias and successful treatment alleviates significant health risks, as well as reducing economic impact due to loss of productivity.[70,71]

In high income countries (HICs), hernia repair is performed with a variety of techniques: open, laparoscopic and in some centres, robotically.[72] The vast majority of repairs (>90%) utilise mesh.[12,73] Tissue based repairs are typically limited to specialist hernia centres[12] or in the setting of strangulated hernias, although there is evidence that mesh can safely be used in these as well.[74-76] In low and middle income countries (LMICs), hernia repair is typically performed as an open procedure, with laparoscopic and robotic repairs limited to urban centres due to resource constraints.[72,77] Mesh is used infrequently, with estimates at <5-15%.[78,79] Tissue repairs are often a modified Bassini as this is less technically complex than the superior Shouldice repair.[12,77]

In HICs, hernia repairs are typically day-case procedures performed by general surgeons or trainees under supervision.[8] In LMICs, inguinal hernia repairs are regularly carried out by non-surgeon physicians and in some cases, health care workers without medical qualifications.[80,81] Day case surgery is uncommon in LMICs[82] despite there being significant evidence that day case surgery is safe, reduces constraints on hospital resources and facilitates early mobilisation.[82-84]

In HICs, inguinal hernias are repaired frequently and close to onset of symptoms[12] due to concerns regarding the risk of hernia complications. In LMICs, the burden of untreated inguinal hernia is high[85] with estimates of prevalence ranging between 3-30%.[78,86,87] The high prevalence of inguinal hernias is a consequence of structural and patient level factors.

Barriers to care in LMICs

There are many barriers to the safe and timely surgical care of inguinal hernias in LMICs. Structural barriers to care encompass the absence of infrastructure, such as roads and hospitals, budgetary prioritisation of traditional public health problems such as maternal and child health and communicable diseases, and a lack of qualified health professionals to facilitate surgery.[72,88,89] These structural barriers fall within the second and third delay categories of "Three Delays" framework used by the Lancet Commission on Global Surgery, that is the delay in patients reaching care and the delay in patient receiving care once they have arrived at the hospital.[90,91] The lack of access to health professionals further compounds the problem of high prevalence of hernias in LMICs.[92] Low rates of repair, less than 40%, in some African countries[4], have resulted in the significant accumulation of cases in the community.[93] Beard et al. estimated this excess surgical caseload to reach 1 million hernias requiring repair over 10 years.[94]

Complication rates in hernia repair in LMICs are also impacted on by the burden of disease and have been reported to be as high as 21%.[95] This likely reflects the significant number of emergent procedures that are undertaken in comparison with HICs.[96] Task shifting of inguinal hernia repair to junior surgical staff, medical officers and non-surgeon health staff

in order to increase access to care may also impact on complications.[97] Finally, limited health care budgets curtail the purchase and use of mesh routinely in most LMICs.[72,87]

Many patient level factors also limit access to timely hernia repair and these fall within the first delay category of the Three Delays Framework.[90,91] These delays in patients seeking care arise from the lack of health literacy regarding the potentially life-threatening complications associated with hernias[87], geographical distance and the challenge of travelling to a hospital for care[98,99] and the financial costs of surgery.[87] These costs, both income lost perioperatively and the supplies and equipment required for surgery and aftercare, are borne by the patient and their family due to the stretched healthcare budgets of LMICs.[71,88,100] The risk of catastrophic expenditure on surgical care, that is expenditure of more than 40% of non-food or 10% of overall household expenditure, is greatest for those in sub-Saharan Africa and south and south-east Asia.[101,102] Health literacy is often most limited in patients with lower socio-economic status and those in rural settings.[4,103] These populations have less access to knowledge about the natural history and treatment of hernia progression and restricted access to healthcare, further worsening outcomes.[104] Rural populations in particular seek out herbal and traditional remedies with hospitals and medical staff being sought out later; this delays early identification and treatment of hernias.[105]

In light of these barriers, when compared with patients in HICs, patients with hernias in LMICs present later, with large inguinoscrotal hernias more frequent and are more commonly treated in emergent settings, presenting with bowel obstruction or strangulation.[95] Historical data suggests over 10% of all hernias treated in LMICs occur in patients with strangulation and mortality rates for these patients approaches 90%[98]; more recent data found that 65% of all hernia repairs in Ghana occur emergently.[99]

Hernia repairs in LMICs are far less likely to be tension-free with less than 5% of all repairs in Africa utilising mesh.[78] While this is likely partly related to higher rates of emergent repair and lack of clinician training and familiarity with hernioplasty, the cost of surgical, hernia-specific mesh presents a significant barrier to its use. In some cases, the cost of mesh accounts for 40-50% of the total operative cost.[106,107] The cost of mesh comprises both the

purchase price, including research and development costs that medical product manufacturers must recover, and import tariffs.

Cost effectiveness of hernia repair in LMICs

Despite these limitations and challenges, elective inguinal hernia repair in LMICs has been shown to be cost-effective, and in terms of its public health impact, comparable to immunisation and malaria prevention measures.[108] Hernias are highly male preponderant and have a particularly high impact on working age men.[4] The associated impacts on the economy broadly and the financial situation of families and communities more locally are significant. The effect on disability adjusted life years (DALYs) is immense – if all symptomatic hernias in Ghana were repaired, five million DALYs would be averted.[94] This combination of significant prevalence and a simple, cost effective solution that averts serious morbidity positions hernia repair as a surgical priority in LMICs.[108]

Use of low cost mesh in hernioplasty

In response to this need, and in order to facilitate access to best practice care, surgeons in LMICs have utilised low cost alternatives, that is, locally available, non-surgical mesh products or more cost effective use of existing products, in hernia repair.[87,109,110] Low cost mesh (LCM) alternatives include mesh designed for use in other settings, such as mosquito netting of varying materials such as polyester, polyethylene, polypropylene and nylon, surgical mesh products that have been resized and resterilised, for example, large 30x30cm flat mesh divided into 7x15cm sections, and indigenous products, either developed locally or fashioning commercially available constructs with flat mesh. The findings of these studies, which include both observational and controlled studies, suggest comparable short and, less frequently, mid-term outcomes for hernioplasty utilising low cost mesh when compared with the published data for surgical mesh.[107] Based on earlier published studies, the charity Hernia International (previously Operation Hernia) has utilised Lichtenstein hernioplasty with low density polyethylene mesh and has reported comparable outcomes.[111]

There are numerous areas of potential areas of concern when using LCM in hernioplasty. The quality of mesh and its physicochemical properties directly impacts on suitability for implantation, ability to be sterilised adequately and surgeon and patient comfort.[109,111,112] Manufacturing standards for LCM vary from medical grade products and contamination with insecticide or other industrial products during manufacture is possible.[62] Supply chain instability due to rapid changes in requirements for non-surgical mesh products or alterations in their physicochemical composition may limit access to suitable products for use in hernioplasty.

In addition, there are the broader concerns with use of mesh in LMICs. The need for adequate training and education for operating medical officers and surgeons in hernioplasty techniques remains significant.[95] Maintaining sterility of mesh[112,113] and the operating theatre environment and ensuring adequate follow up of patients so that complications can be detected are also ongoing challenges in LMICs.[114,115]

Hernia repair outcomes

When considering studies on hernia repair, the most important and commonly reported outcomes are postoperative pain and hernia recurrence.[56] Postoperative infection, superficial and deep, seroma, haematoma, duration of stay, and return to function are also frequently reported.[12] These predominantly procedural and operative outcome measures have been expanded more recently to include patient-centric measures such as level of function and discomfort.[116] As different mesh constructs have been developed, operative time and surgeon satisfaction or ease of use have also been reported. For the use of low cost mesh alternatives, the physicochemical properties, sterility and safety issues need to be considered individually as these products are not designed for use in humans.[113]

Infection

Elective inguinal hernia repair is classed as a clean operation.[117] Compared to high risk environments (typically LMICs), postoperative infection rates in hernioplasty in low risk environments (HICs or well-resourced centres in LMICs) are much lower.[12] Infection rate varied with type of mesh inserted and rates for the most commonly used polypropylene

meshes range between 2.5-5.9%.[33] This is similar for polyester, although some studies report infection rates up to 16%.[33] Duration of infection has been reported up to 39months postoperatively[118], although significant infections often present much earlier. In LMICs, rates of infection in inguinal hernia are harder to determine due to challenges with data availability but recent studies suggest higher rates of infection ranging between 3-7.8%.[84,110] Historically, infection rates have been much higher but this is due in part to higher rates of late presentation with obstructed or incarcerated hernias.[119]

Infection in hernioplasty can be divided into superficial and deep infection; superficial infection is limited to the subcutaneous tissues not involving the mesh construct and deep infection involves the deep soft tissues and implant.[120] The latter has significant impacts, requiring treatment with long courses of antibiotics or removal of the implant, also known as explantation.

Seroma

Seroma is the postoperative accumulation of serous fluid within the surgical wound.[121] The aetiology of seroma is not completely understood but is thought to be a consequence of an inflammatory reaction and is impacted on by extent of dissection and presence of dead space.[121] Rates of seroma in inguinal hernia repair range between 0.5-12.2% and most resolve within 6-8 weeks.[11,12] When the seroma impinges on function, is causing pain or appears to be infected, aspiration may be performed, either percutaneously or by open drainage.

Haematoma

Haematoma is the postoperative accumulation of blood in the wound or within the scrotum. Wound haematoma rates range between 6-16%[11] and 4.5% for scrotal haematoma.[10] Management is often non-operative and the haematoma may spontaneously discharge through the wound if it is not reabsorbed. Aspiration or evacuation may be necessary if there is ongoing pain, limitation of function, increase in size or evidence of infection.[11]

Recurrence

Recurrence is one of the key outcomes measured in hernia repair and the low rate of recurrence is the reason that hernioplasty has overtaken tissue-based repairs in popularity.[8] Recurrence rates in Lichtenstein hernioplasty vary and have been reported between 1-5.6%.[22,24,25,122] This is consistently favourable when compared with tissue repairs[22,24,123], with recurrence rates of over 10% at the beginning of the 20th century.[13] Recurrence in hernioplasty is usually technical and occurs at mesh borders, rather than through the mesh.[8,13] This can be due to either inadequate size of mesh, insecure fixation or missed hernia.[12] Operator experience is also an important factor, with novice surgeons having higher recurrence rates.[124] The timing of hernia recurrence is not clearly understood but there is a linear increase in recurrence rate over the years after surgery.[125] A large portion (38%) of recurrences occur within the first 5 years postoperatively[126,127] but continue occur well beyond this period.[128] At least 5 years of follow up are required to assess recurrence rates[129] and 10 years of follow up provides the most accurate information.[128]

Explantation

Explantation is the removal of the inguinal hernia mesh.[130] This is most commonly due to recurrence of the hernia but can also be due to chronic pain or infection.[130] If required, explantation of mesh typically occurs between 2-3 years after initial surgery.[12]

Pain

Acute and chronic pain are common after hernia repair. Acute pain usually settles in the immediate postoperative period and may be directly related to intraoperative complications, such as nerve entrapment.[8] Chronic pain is a complex, multifactorial problem with neuropathic and nociceptive elements.[131] Chronic pain in general has been defined as pain lasting more than 3 months.[132] The definition of chronic post inguinal herniorrhaphy pain (CPIP) is debated due to the prolonged inflammatory response provoked by mesh.[133] It has been proposed that a 6 month duration should be used instead.[133] Rates of CPIP range between 0.7-43% due to varied definitions, means and timepoints of measurement.[134] The prevalence of debilitating CPIP impacting on normal daily activities or work is estimated to be 0.5-6%[134] with rates reducing over time.[135]

Patient satisfaction

Patient satisfaction can be measured using a number of different scales including the visual analogue scale (VAS) for pain and various quality of life scoring systems, including some specifically designed for inguinal hernia. In addition, there are some culturally contextualised versions of these questionnaires. These scales utilise a combination of preoperative and postoperative pain, level of function and cosmesis.

Surgeon satisfaction

Surgeon satisfaction is typically assessed with simple Likert style scoring scales, on ease of use and similarity to other products. This is relevant for use when comparing low cost mesh with surgical mesh, in particular, substitute mesh products such as mosquito netting and resterilised mesh.

Physicochemical properties

Physicochemical properties of the mesh construct include the material it is made from, the structure of mesh filaments, denier, weight, pore size, tensile strength and anisotropy. These are important to know as they facilitate comparison with surgical mesh products and thereby allow for assessment of suitability for use. The ability of mesh to be sterilised can be inferred from the melting point of the material, which dictates whether sterilisation via steam autoclave, the most easily accessible sterilisation technique in LMICs, is feasible.[62] Steam sterilisation at 134°C is required in HICs but there is evidence that sterilisation at 121°C does not increase infection rates when using LCM.[112]

Cost

Cost and difficult access to surgical products limits their use in LMICs. This is the basis for substitution of products and a key driver of innovation.[136] Substitution of products has a long history in LMICs and includes the use of nylon fishing wire as suture material and the development of the Bogota bag in laparostomy.[136] Low cost mesh is cheaper than surgical mesh but has other costs – time spent researching product specifications, independently

testing material for strength and structural integrity, sterilisation and preparation of the mesh and staff training and time costs.[137]

Context of review question

The scope of this systematic review and meta-analysis is to assess outcomes after hernia repair using low cost mesh in low and middle income countries. A search of PROSPERO, PubMed, the Cochrane Database of Systematic Reviews and JBI Evidence Synthesis was conducted and identified three previous systematic reviews, two of which include a meta-analysis, considering the use of non-surgical mesh in hernia repair.[86,107,138] Ahmad et al. and Patterson et al. both performed a meta-analysis and focused on postoperative outcomes.[86,138] Sørensen and Rosenberg conducted a systematic review of the literature across three databases in 2012.[107] All of these provide helpful assessment of the literature and are positive about the use of mosquito netting in place of surgical mesh. Yang et al. conducted a literature review in 2011, identifying the same studies as Sørensen and Rosenberg.[87] The characteristics of these studies are provided in Table 1.

However, there are limitations to the extent of the review and analysis process as conducted by these authors, with relatively few databases included, relevant RCTs excluded and the analysis confined to postoperative outcomes. Inclusion of mosquito net mesh broadly does not account for the varied materials that comprise mosquito net at structural level and there is a need to consider these at a more granular level. There is also a growing body of evidence published regarding the use of low cost meshes other than mosquito netting, such as resterilised surgical meshes and indigenous products, and the outcomes of these alternative low cost meshes have not been assessed.

Table 1. Existing reviews in the literature

Author	Year published	Search conducted	Grey literature	Protocol	Bias assessment	RCT only	Meta-analysis	Studies included	Issues
Ahmad	2019	Aug 2018	No	Yes; unpublished	Yes	No	Yes	Chauhan 2007 Freudenberg 2006 Löfgren 2016 Tongaonkar 2003	Tongaonkar – non-randomised study
Patterson	2017	Sep 2016	Yes	No	Yes	Yes	Yes	Darokar 2016 Dubey 2014 Freudenberg 2006 Gundre 2012 Löfgren 2016	Dubey – incisional hernia
Sørensen	2012	Not stated	No	No	No	No	No	Chauhan 2007 Clarke 2007 Freudenberg 2006 Stephenson 2011 Tongaonkar 2003 Wilhelm 2007	Stephenson – observational study; included ventral hernias Wilhelm – animal study in goats
Yang	2011	Not stated	No	No	No	No	No	Chauhan 2007 Clarke 2007 Freudenberg 2006 Tongaonkar 2003	Tongaonkar – non-randomised study

The HerniaSurge plan for safe inguinal hernia repair in LMICs is to promote and disseminate simple guidelines, work towards sustainable strategies independent of international aid and focusing on high volume Lichtenstein repair under LA using low cost mesh alternatives.[12] This requires confidence in the literature, an understanding of the benefits of different types of low cost mesh and a clear summation of the risks involved in using LCM and how to mitigate these risks. This review aims to build on the extant reviews by conducting an up to date review of the literature, across a wider set of databases and grey literature sources, including low cost mesh alternatives in addition to mosquito netting and consider outcomes such as patient and surgeon preference, sterility and recurrence alongside a more granular assessment of complication rates. This would assist clinicians in LMICs in their decision-making regarding use of low cost mesh, in particular, identifying potential areas for improvement of practice with regards to sterility and mesh choice. It may also facilitate downward pressure on the purchase costs of surgical mesh in LMICs at the health systems level.

Statement of review question

What are the differences in surgical outcomes between hernioplasty using low cost and surgical mesh in adults undergoing elective hernioplasty in low and middle income countries?

Overview of evidence synthesis

Evidence based healthcare has been defined as clinical decision making that considers feasibility, appropriateness, meaningfulness and effectiveness of healthcare practices, informed by the best available evidence, the context in which care is delivered, the

individual patient and the professional judgement and expertise of the health professional.[139] This definition is built on the concept of evidence based medicine articulated by Guyatt in 1991[140], which marked a shift away from anecdotal, experience guided practice towards critical analysis of the evidence supporting and driving healthcare professionals' clinical engagement with patients. Sackett further refined the definition of evidence-based medicine as "the conscientious, explicit and judicious use of current best evidence about the care of individual patients".[141] These definitions highlight the challenges of modern healthcare for practitioners. The volume of published content is enormous and increasing exponentially.[142-144] The capacity for an individual or group of practitioners to summarise current best evidence is limited by the significant clinical, administrative and extra-clinical pressures facing many health professionals.[145] This is especially pronounced in LMICs, where the high burden of disease positions meeting clinical need as the highest priority to the detriment of other aspects of healthcare provision.[146,147] Summarising the literature and judiciously applying it to individual patients requires identifying relevant studies, analysis of the study design, context, objectives, statistical tests utilised and their appropriateness and weighting of individual study findings against others.[148,149] For practitioners in LMICs, key barriers to implementation of evidence-based practice include access to current information, skills and training in critical appraisal and resource shortages.[146,150] The lack of locally applicable research further limits ability to inform both clinical practice and health policy.[151,152]

In this context, the expanding role and relevance of reviews of the literature are apparent. Systematic reviews are a structured approach to summarising and synthesising existing knowledge relevant to a particular question.[153] They began to appear in the literature in the

1970s and 1980s[143] and often included a meta-analysis. Meta-analysis is the quantitative synthesis of primary data to yield an overall summary statistic.[154] Systematic reviews aim to minimise bias through following pre-defined processes and structured, explicit methods thereby allowing practitioners to utilise their findings in a reliable and meaningful way.[153,155,156] Ultimately, systematic reviews are the gold standard to search for, collate, critique and summarise the best available evidence regarding a clinical question.[157] The quality of a systematic review is dependent on the minimisation of risk and error during the review process; this includes the methods used to conduct the review, analyse the data and the quality of the studies included.[144,153,157] Thus, a well-conducted systematic review and meta-analysis of randomised controlled trials is the highest level of evidence available to practitioners regarding a question of effectiveness of an intervention.[144,158]

Acknowledging the rapid expansion of the published literature, with at times, varying quality of work, a number of systematic approaches to reporting and reviewing have been developed. These include the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) tool and the Consolidated Standards of Reporting Trials (CONSORT) checklist for reporting randomised controlled trials.[156,159] Transparent standards allow for some of the weaknesses inherent in evidence-based healthcare to be overcome, such as the exclusion of negative trial results from publication in journals in preference to equivocal or potentially clinically irrelevant but significant positive trial findings.[144,160,161]

JBI's approach to evidence-based practice is centred around clinical decision making that is informed by the best available evidence, delivered in a contextually and culturally appropriate manner, considers the preferences of the healthcare consumer and accounts

for the judgement of the health professional.[162] Evidence-based practice is an iterative process that progresses through evidence generation, synthesis, transfer, utilisation and ultimately, impacting health practices and outcomes globally.[163] Evidence synthesis is the evaluation or analysis of research evidence and opinion on a specific topic to aid in decision making in healthcare.[164] In the JBI model, the outputs of evidence synthesis are guidelines, evidence summaries and systematic reviews.[163]

Figure 1. JBI Model of Evidence-Based Healthcare

From "Redeveloping the JBI Model of Evidence-Based Healthcare" Jordan et al. 2018.[165]

Discussion of methodological approach taken

The process of conducting a systematic review falls within the evidence synthesis component of the JBI model. It is the evaluation, analysis and collation of research evidence on a topic and is a form of secondary research.[163]

A rigorous systematic review of a therapeutic intervention should have a well-defined review question, identifying the population of interest, the intervention and comparator being assessed and clearly defined outcome measures.[166] Study inclusion and exclusion criteria should be defined and a search strategy developed that is both sensitive and precise, recalling relevant studies while excluding irrelevant studies, across multiple databases and including the grey literature.[155,167] One of the benefits of JBI is access to a global collaborative research network that is multi-lingual, facilitating searching across language and thereby increasing the scope to identify relevant studies.[167]

Independent dual reviewer assessment of the search results, quality assessment of the included studies and extraction of the data should be performed.[166,168] Statistical analysis should be conducted appropriately, with pre-defined outcomes and subgroup analyses identified prior to commencement and tests for heterogeneity utilised.[166,169] Reporting should follow PRISMA guidelines and a GRADE Summary of Findings table produced.[156,166,170]

This approach was taken for this review in keeping with JBI methodology.[166] The systematic review protocol was published on PROSPERO (CRD CRD42019136028) and the protocol published prior to commencement.[171]

Assumptions and limitations

Fundamentally, even a well conducted, rigorous and transparent systematic review and meta-analysis is beholden to the quality of studies included and is relevant until such a time as practice changes or knowledge gained challenges previous understandings.[172] By limiting studies to randomised controlled trials only, this review minimises potential sources of

bias.[170] Nevertheless, RCTs in LMICs do face particular challenges such as higher rates of patient attrition during follow up, alongside more common difficulties in study design, including outcome definition and adequate reporting in line with CONSORT checklist.[173-176]

Chapter 2: Methods and Methodology

Review Objectives

The objective of this review was to assess the difference in surgical outcomes between inguinal hernioplasty utilising low cost mesh and surgical mesh in adults undergoing elective hernioplasty or emergent hernioplasty without bowel resection in low and middle income countries.

Primary outcomes of interest for this review were rates of postoperative pain, wound infection (superficial and deep), wound collection (seroma and haematoma) and hernia recurrence. Secondary outcomes were patient and surgeon satisfaction, durability and sterility of mesh and cost.

Criteria for Considering Studies for this Review

Types of Studies

This review included only experimental study designs, either randomised or quasi-randomised (i.e. systematic but not random allocation) controlled trials. This was decided upon considering the presence of a number of randomised controlled trials in the literature, enabling minimisation of potential bias to improve the reliability of the review findings.

Types of Participants

This review included adult patients undergoing elective and emergent inguinal hernia repair without resection of bowel in low and middle income countries. Low, lower middle and upper middle income countries as defined by the World Bank country classification list were considered for inclusion.[177]

Specific exclusion criteria were patients presenting for emergent hernia repair requiring bowel resection.

Types of Interventions

This review considered studies that evaluated low cost mesh used in hernia repair, including non-surgical mesh such as mosquito net, resterilised commercial mesh and indigenous prostheses. The surgery may be performed by any surgeon, regardless of their training or level. No studies were excluded based on the clinical setting for the surgery (i.e. tertiary hospital, district hospital).

Types of Comparators

This review considered studies that compared the intervention to hernia repair utilising surgical mesh, that is, commercially produced and marketed products for use in human inguinal hernia repair.

Types of Outcome Measures

This review considered studies that included any of the following primary outcomes: rates of postoperative pain, wound infection (both superficial and deep), wound collection (both seroma and haematoma) and hernia recurrence.

Secondary outcomes included any of: patient and surgeon satisfaction, durability and sterility of mesh and cost.

Outcome measurement and definitions

Postoperative pain was measured based on patient report on any identified scale used pre- and postoperatively, or postoperatively only; this included incidence of chronic pain, as reported by study authors.

Superficial wound infection was defined as any infection not involving the mesh and treated with antibiotic therapy or wound dressings; deep infection was infection involving mesh and requiring long-term suppressive antibiotic therapy or mesh explantation.

Wound collection was defined as either clinically detected collection not requiring draining, or spontaneous drainage of serous fluid (seroma) or blood (haematoma) or collection requiring drainage, either percutaneous or formal surgical drainage.

Hernia recurrence was defined as any recurrence of a groin hernia after mesh repair.

Secondary outcomes assessed were patient and surgeon satisfaction, on any scale utilised by authors, durability and sterility, based on mechanical or histological analysis, and cost, compared against commercial mesh available in the same context.

Review Methods

Search Strategy

The search strategy aimed to locate both published and unpublished studies. An initial limited search of PubMed and Embase was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles and the index terms used to describe the articles were used to develop a full search strategy for PubMed. The search strategy, including all identified keywords and index terms, was adapted for each included information source. The reference lists of all studies selected for critical appraisal were screened for additional studies.

Information sources included electronic bibliographic databases and trial registers; sources of unpublished studies and grey literature were trial registers, institutional repositories and websites of relevant organisations, such as Operation Hernia. Hand searching of existing systematic reviews and identified relevant studies was conducted in order to identify any further relevant original studies.

Electronic bibliographic databases searched were: PubMed, Embase, Scopus, Web of Science, and the Cochrane Library. Grey literature and trial registers searched were: Cochrane Controlled Register of Trials (CENTRAL), ProQuest, Web of Science Conference Proceedings, MedNar, ClinicalTrials.gov and the World Health Organization International

Clinical Trials Registry Platform. Google Scholar was the only search engine utilised for the identification of grey literature.

The keywords identified and used to construct the search strategy were:

Hernia, Hernia repair, Inguinal hernia, Inguinal hernia repair, Hernioplasty, Mesh repair, Lichtenstein repair, Groin hernia, Groin hernia repair, Tension free repair, Herniorraphy

Mesh, Mosquito net, Mosquito net mesh, Low cost, Low cost mesh, Hernia implants, Resterili* mesh, Sterili* mesh, Surgical mesh, Commercial mesh, Polypropylene, Polyethylene, Nylon, Polyester, Non-commercial mesh, Prosthesis, Low Density Polyethylene

Based on this, the full search strategy was constructed and is listed below for PubMed:

Search (((((("Hernia"[Mesh] OR "Herniorrhaphy"[Mesh] OR "Hernia/surgery"[Mesh]))) OR ((Hernia[Title/Abstract] OR Hernia repair[Title/Abstract] OR Inguinal hernia[Title/Abstract] OR Inguinal hernia repair[Title/Abstract] OR Hernioplasty[Title/Abstract] OR Mesh repair[Title/Abstract] OR Lichtenstein repair[Text Word] OR Groin hernia[Text Word] OR Groin hernia repair[Text Word] OR Tension free repair[Text Word] OR Herniorraphy[Text Word]))))) AND ((((("Surgical Mesh"[Mesh] OR "Mosquito Nets"[Mesh] OR "Culicidae"[Mesh]))) OR ((mesh[Title/Abstract] OR Mosquito net[Title/Abstract] OR Mosquito net mesh[Text Word] OR Low cost[Text Word] OR Low cost mesh[Text Word] OR Hernia implants[Text Word] OR Resterilized mesh[Text Word] OR Sterilized mesh[Text Word] OR resterilised mesh[Text Word] OR sterilised mesh[Text Word] OR Surgical mesh[Text Word] OR Commercial mesh[Text Word] OR Polypropylene[Text Word] OR Polyethylene[Text Word] OR Nylon[Text Word] OR Polyester[Text Word] OR Non-commercial mesh[Text Word] OR Prosthesis[Text Word] OR Low density polyethylene[Text Word]))) Filters: Publication date from 2000/01/01

The remaining database search strategies are listed in Appendix I.

Following the search, all identified records were collated and uploaded into Endnote V9.3.3 (Clarivate Analytics, PA, USA) where any duplicates were removed. Titles and abstracts were screened by two independent reviewers (AV and YJ) for assessment against the inclusion criteria for the review. Potentially relevant studies were retrieved in full and assessed in detail against the inclusion criteria by two independent reviewers (AV and YJ). Reasons for exclusion of full text studies that did not meet the inclusion criteria were recorded and

reported in a PRISMA flow diagram. Disagreements that arose between the reviewers at each stage of the study selection process were resolved through discussion.

Assessment of Methodological Quality / Critical Appraisal

All included studies were critically appraised by two independent reviewers (AV and ZM or THB) at the outcome level for methodological quality in the review using version 2 of the Cochrane risk-of-bias tool for randomised trials (RoB2).[178] Authors of papers were contacted to request missing or additional data or for clarification of questions, although this was not always successful (see Table 2 for additional information requested). Disagreements that arose were resolved through discussion and with a third reviewer when required (ZM or THB). The results of critical appraisal are reported in both narrative and tabular form (see Table 4 – Cochrane Risk of Bias Outcomes; Figure 3 – Cochrane Risk of Bias Outcomes).

Table 2. Additional information requested from study authors

Study details	**Requested information**	**Response obtained**
Chauhan 2007	Presence of follow up study	Yes; no study published
Darokar 2015	Raw patient data, definition of wound infection, randomisation process	No response
Escobedo 2018	Raw patient data, definition of wound infection and chronic pain, sterilisation method	No response
Freudenberg 2006	Raw patient data, randomisation process	No response
Gundre 2011	Raw patient data, definition of wound infection, additional reference	No response
Jain 2016	Raw patient data	Yes; limited patient data
Pathan 2018	Raw patient data, randomisation process, follow up protocol	No response
Pradhan 2020	Raw patient data, randomisation method, blinding, clarification of discrepancy in patient group allocation, treatment of bilateral hernias	No response
Wani 2019	Raw patient data, definition of wound infection and chronic pain, cost of mesh, sterilisation method	No response

The results of the critical appraisal were used to inform the analysis and interpretation of the results. Results of critical appraisal were not used as a basis to subsequently remove studies from the review.

Data Extraction

All studies, regardless of the results of their methodological quality, underwent data extraction and synthesis (where appropriate) by 2 independent reviewers (AV and YJ), using a data extraction tool (see Appendix 2). Data extracted included specific details about the populations, study methods, interventions and outcomes of significance to the review objectives.

Direct contact with researchers was sought for clarity regarding missing data and any disagreements that arose between the reviewers were resolved through discussion or with input from a third reviewer (ZM or THB).

Data Synthesis

Studies were, where appropriate, pooled in statistical meta-analysis using RevMan V5.4. (Copenhagen: The Nordic Cochrane Centre, Cochrane). Effect sizes were expressed as either relative risks (for dichotomous data) and weighted (or standardised) final post-intervention mean differences (for continuous data) and their 95% confidence intervals calculated for analysis. Heterogeneity was assessed using the Cochran's Q test and the I squared statistic. Statistical analysis was performed using a random-effects model when five or more studies were included in the meta-analysis. The random effects model facilitates the generalisation of findings beyond the included studies (an assumption of distribution of effects).[179] When there were less than five studies, a fixed-effect model was considered where appropriate.[179]

Sensitivity analyses were conducted to test assumptions about the meta-analytic models used. When statistical pooling was not possible, the findings were presented in narrative form including tables and figures to aid in data presentation.

A funnel plot was generated using RevMan V5.4. (Copenhagen: The Nordic Cochrane Centre, Cochrane) to assess publication bias when there were 10 or more studies included in a single meta-analysis. Statistical tests for funnel plot asymmetry (Egger test, Begg test, Harbord test) were performed where appropriate.

Modifications made to published protocol

The protocol for this systematic review and meta-analysis was published prior to commencement.[171] Modifications made to the published protocol included additional searching through Google Scholar and inclusion of inguinal hernias undergoing emergent repair but not requiring bowel resection.

Chapter 3: Results

This chapter presents the findings of the systematic review and the results of the meta-analyses conducted. In keeping with the published study protocol and JBI methodology, the search strategy and details of study selection process, critical appraisal utilising the Cochrane Risk of Bias 2 (RoB2) tool, meta-analyses conducted utilising RevMan v5.4 and a Summary of Findings table produced using GRADEPro GDT are presented below.

Summary of Findings: Low cost mesh compared to surgical mesh for hernioplasty

Patient or population: patients undergoing elective primary inguinal hernioplasty
Setting: low and middle income countries
Intervention: low cost mesh
Comparison: surgical mesh

Certainty assessment							Summary of findings				
							Study event rates (%)			Anticipated absolute effects	
Participants (studies) Follow up	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Overall certainty of evidence	With surgical mesh	With low cost mesh	Relative effect (95% CI)	Risk with surgical mesh	Risk difference with low cost mesh
Recurrence											
1248 (9 RCTs)	serious [1]	not serious	not serious	serious [a]	none	⨁⨁◯◯ LOW	1/627 (0.2%)	2/621 (0.3%)	**RR 1.44** (0.23 to 9.04)	2 per 1,000	**1 more per 1,000** (from 1 fewer to 13 more)
Chronic pain											
569 (5 RCTs)	serious [2]	not serious	not serious	serious [b]	none	⨁⨁◯◯ LOW	9/286 (3.1%)	6/283 (2.1%)	**RR 0.68** (0.24 to 1.92)	31 per 1,000	**10 fewer per 1,000** (from 24 fewer to 29 more)
Superficial infection											
1348 (11 RCTs)	serious [3]	not serious	not serious	serious [c]	none	⨁⨁◯◯ LOW	22/678 (3.2%)	18/670 (2.7%)	**RR 0.84** (0.46 to 1.54)	32 per 1,000	**8 fewer per 1,000** (from 18 fewer to 18 more)

Deep infection

1348 (11 RCTs)	serious [3]	not serious	not serious	very serious [d]	none	⨁◯◯◯ VERY LOW	0/678 (0.0%)	1/670 (0.1%)	**RR 2.94** (0.12 to 71.15)	0 per 1,000	**0 fewer per 1,000** (from 0 fewer to 0 fewer)

Explantation

1288 (10 RCTs)	serious [4]	not serious	not serious	very serious [e]	none	⨁◯◯◯ VERY LOW	0/647 (0.0%)	2/641 (0.3%)	**RR 2.93** (0.31 to 27.71)	0 per 1,000	**0 fewer per 1,000** (from 0 fewer to 0 fewer)

Seroma

1238 (7 RCTs)	serious [5]	not serious	not serious	not serious	none	⨁⨁⨁◯ MODERATE	14/617 (2.3%)	16/621 (2.6%)	**RR 1.06** (0.53 to 2.11)	23 per 1,000	**1 more per 1,000** (from 11 fewer to 25 more)

Haematoma

974 (6 RCTs)	serious [6]	not serious	not serious	not serious	none	⨁⨁⨁◯ MODERATE	41/488 (8.4%)	40/486 (8.2%)	**RR 1.01** (0.69 to 1.49)	84 per 1,000	**1 more per 1,000** (from 26 fewer to 41 more)

Postoperative pain

299 (2 RCTs)	not serious	not serious	not serious	not serious	none	⨁⨁⨁⨁ HIGH	152	147	-	The mean postoperative pain was **0**	MD **0.07 lower** (0.27 lower to 0.14 higher)

CI: Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

Explanations

1. Overall RoB2 scores for this outcome ranged from low (4 studies), some concerns (4 studies) to high (1 study)
2. Overall RoB2 scores for this outcome ranged from low (2 studies), some concerns (3 studies) and high (1 study)
3. Overall RoB2 scores for this outcome ranged from low (4 studies), some concerns (5 studies) and high (2 studies)
4. Overall RoB2 scores for this outcome ranged from low (4 studies), some concerns (5 study) to high (1 study)
5. Overall RoB2 scores for this outcome ranged from low (2 studies), some concerns (4 studies) to high (1 study)
6. Overall RoB2 scores for this outcome ranged from low (4 studies), some concerns (1 study) and high (1 study)

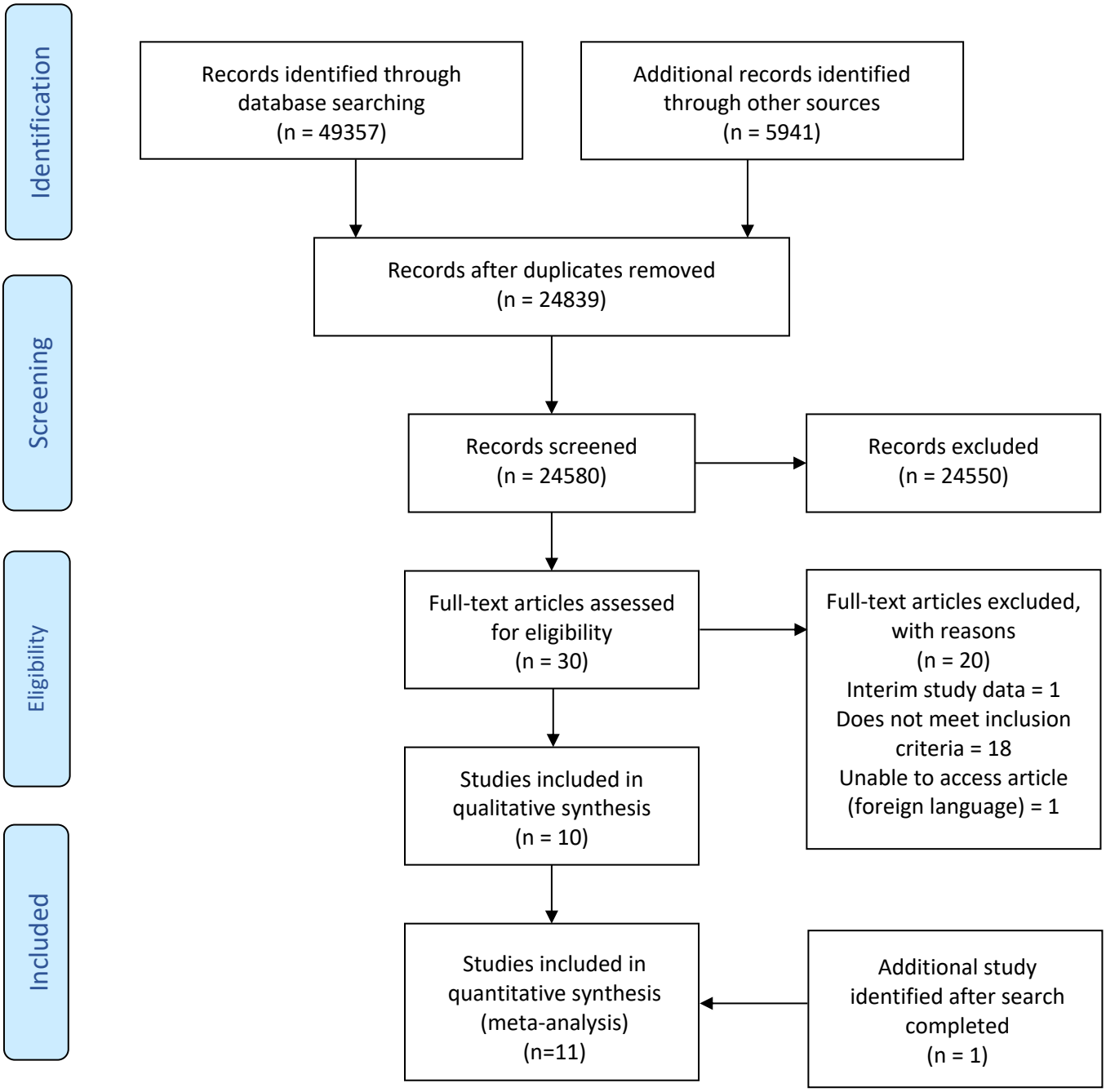
a. Downgraded 1 level due to imprecision; wide CI, OIS conducted, sample size satisfactory
b. Downgraded 1 level due to imprecision; OIS conducted, sample size unsatisfactory
c. Downgraded 1 level due to imprecision; OIS conducted, sample size unsatisfactory
d. Downgraded 2 levels due to imprecision; wide CI, OIS conducted, sample size unsatisfactory
e. Downgraded 2 levels due to imprecision; wide CI, OIS conducted, sample size unsatisfactory

Description of search strategy and study selection

After completion of searching, 55298 records were identified. After removal of duplicates, 24839 records remained. 39 studies were excluded due to date of publishing prior to 2000. 24580 records were then screened by title and abstract. Of these, 24550 records were excluded for not meeting inclusion criteria and 30 articles were extracted for full-text screening. At the conclusion of full text review, 10 studies satisfied inclusion and exclusion criteria and proceeded to critical appraisal. No studies were excluded after critical appraisal. These 10 studies were included in the meta-analysis. Reasons for exclusion after full text review are included below in the PRISMA diagram (see also Table 4).

Additional monthly searches of PubMed were conducted after the final complete database and grey literature searches in November 2019 up until October 2020. This detected one further suitable study, which was critically appraised and included in the meta-analysis.

Figure 2. PRISMA Flow Diagram



Description of included studies

The 11 studies included in this systematic review were conducted across five countries: India[106,180-185], Turkey[186], Mexico[187], Burkina Faso[109] and Uganda.[188] The total number of included patients was 1306 and 1403 inguinal hernias were identified. However, four studies did not record total number of hernias operated on and as bilateral hernias were included in their datasets, this number may underreport total treated hernias.[106,180,181,185] Study sizes ranged from 28[187] to 302 patients.[188] The earliest study was published in 2005[186] and the latest in 2020.[185]

All studies used qualified general surgeons as primary operators[106,109,180-188], with nine hospitals being associated with a medical college or university.[106,109,181-187] Ten of the study sites were urban hospitals,[106,109,180-187] albeit in cities of various size and in states of varying economic status, with only one being in a rural location.[188]

The patient population age ranged between 17[181] and 90[186] and there was a large male preponderance in the nine studies that recorded gender breakdown with 1193 men and 26 women.[106,180-183,185-188] American Society of Anaesthesia Physical Classification (ASA) score[189] was recorded in 5 studies.[109,184,186-188] All patients except one were initially classed as ASA I-II. Retrospectively, one further patient in the Löfgren study was upgraded to an ASA score of III based on extra information obtained from the relatives after an adverse event.[188]

Operatively, nine studies recorded anaesthetic type[106,109,180,182-186,188] and 96 procedures were performed under a general anaesthetic, 743 under spinal anaesthesia and 374 under local anaesthesia. Antibiotic prophylaxis was documented in 10 studies[106,109,180-182,184-188] and antibiotics were given in seven studies[106,109,181,184,185,187,188], penicillins in three[106,109,188], cephalosporins in two[184,187] and fluroquinolones in two.[181,185] Two studies provided routine postoperative antibiotics.[182,185] Lichtenstein repair was performed in 10 studies[106,109,181-188] and the Prolene Hernia System used in one study.[180] Mesh sterilisation technique was recorded in nine studies[106,109,180-183,185,186,188] with steam autoclave used in five studies[109,182,183,186,188] and ethylene oxide in three studies.[106,181,185] One study refashioned

surgical mesh intraoperatively; this almost certainly would have been sterilised as per industrial standards using ethylene oxide but the authors did not state this explicitly.[180]

Mean duration of follow up was recorded by nine studies[106,109,180,182-185,187,188] and ranged from 10 days[185] to 20 months.[106] Median duration of follow up to 24 months was reported by one study.[186] One study stated follow up ranged between two to five years.[181] Loss to follow up was poorly documented in most studies but was minimal, based on results presented regarding outcomes. Most studies had three or more postoperative reviews[106,180-182,184-187] and the majority of studies had multiple reviews within the first week.[180-182,185,186]

Chauhan et al. randomised 84 patients, 44 to the Prolene Hernia System and 40 to a homemade bilayer device constructed using flat polypropylene mesh, a surgical product.[180] Recurrent hernia and complicated inguinal hernias, although this was not further defined, were excluded. The study was conducted as a pilot study and was powered for detecting a 25% difference in operating time, not complications. Accordingly, complications were recorded as a secondary outcome. The study was double blinded (surgeon and assessor) and outcomes were operating time, pain, infection, haematoma, recurrence and explantation. Follow up was carried out to 12 months postoperatively.

Cingi et al. compared polypropylene mesh to resterilised mesh, that is, a large flat polypropylene mesh that has been resized and is sterilised and repackaged on site prior to use.[186] This has the advantages of using surgical mesh while reducing the cost per cm^2.[186] Steam sterilisation was utilised. This study was single blinded (assessor) and 198 patients were randomised to either resterilised mesh (n=93) or to the control polypropylene mesh (n=91). Patients with recurrent or bilateral hernias, incarcerated hernias requiring emergency operations, ASA score > 2, age < 18 years or with remote infections were excluded. Outcomes assessed were operative time, length of stay, haematoma, infection, recurrence and explantation. Duration of follow up was up to 3.5 years. This study also considered the effect of resterilisation on mesh and specifically conducted mechanical strength testing on representative samples.

Darokar et al. compared mosquito net mesh, not further defined, against polypropylene mesh.[106] In total, 73 patients were randomised and 78 hernias operated on. Blinding of patients and assessors was not mentioned and the process of randomisation of bilateral hernias was also unclear. This study excluded patients with recurrent hernias and strangulated hernias requiring resection. The authors did include eight patients who underwent emergency operation for obstructed hernias, however. Of these, six patients were allocated to the surgical mesh group and two to the mosquito net mesh group. Antibiotics were provided postoperatively in three patients, two patients receiving three postoperative doses (one patient in each arm) and one patient in the surgical mesh group receiving seven postoperative doses. Outcomes assessed were seroma, haematoma, infection, postoperative neuralgia, recurrence and explantation. Mean follow up duration in this study was 20 months, ranging from 7 to 30. Mesh was sterilised using ethylene oxide (ETO) gas.

Escobedo et al. conducted a double blind (patient and assessor) trial of 28 patients with 31 hernias to either a low density polyethylene (LDPE) or polypropylene mesh, with 16 patients in the LDPE group and 15 in the polypropylene group.[187] Patients with bilateral hernias had each side independently randomised. Primary outcomes were pain, postoperative neuralgia, infection, recurrence and explantation. Cost was a secondary outcome. Follow up was 18 months. Immunocompromised patients and those with incarcerated hernias and recurrent hernias were excluded from the trial. Of the patient population, one patient in the polypropylene mesh group was classified as ASA IV and the remainder were ASA I or II.

Freudenberg et al. randomised 35 patients with 40 hernias to either nylon mosquito net mesh or Ultrapro® mesh, a partially absorbable polyglactin/polypropylene product.[109] The trial was double blinded (patient and assessor). Bilateral hernias were treated independently and randomised. This study aimed to assess patient pre- and post-operative quality of life utilising a locally adapted questionnaire tool and the follow up period was limited to 30 days. Secondary outcomes were surgeon comfort, infection and explantation.

Gundre et al. recruited 70 patients in their single blinded (patient) RCT comparing high density polyethlyene (HDPE) to polypropylene, with 35 patients in each arm.[181] Patients that were immunocompromised, had diabetes or hypertension or had incarcerated, strangulated or recurrent hernias were excluded from the trial. Primary outcomes were surgeon satisfaction, postoperative pain, seroma, wound infection, recurrence and explantation. The follow up duration was 5 years, and sterilisation was performed with ETO.

Jain et al. randomised 170 patients with 215 hernias to either HDPE or polypropylene. The study was double blinded (patient and assessor).[182] Patients with immunocompromise, bleeding diatheses, an ASA score > 3, and recurrent, obstructed or strangulated hernias were excluded. Patients with bilateral hernias acted as their own control. Outcomes were postoperative pain, seroma, haematoma, infection and recurrence. This study reported 16 patients lost to follow up in total but did not provide information on intervention and comparator group loss to follow up.

Löfgren et al. conducted a double blind (patient and assessor) RCT enrolling 302 patients with unilateral hernias.[188] Patients with femoral hernias, substance abuse or suspected or confirmed coagulopathy were excluded. Primary outcomes measured were postoperative complications: infection, seroma, haematoma, postoperative pain, postoperative neuralgia and recurrence. Secondary outcomes were patient satisfaction and self-assessed groin symptoms. Follow up duration was 12 months, and at 12 months, 8 patients were lost to follow up from the intervention group and 5 patients from the control group. The study was designed as a superiority trial and thus cannot be interpreted to show non-inferiority of the low cost mesh alternative.

Pathan et al. randomised 200 patients with 224 hernias, equally divided to either HDPE mosquito net mesh or Prolene® (polypropylene) mesh.[183] It was not clear whether blinding of patients or assessors was undertaken. The treatment of bilateral hernias was also unclear; the study authors reported that bilateral hernias were treated as a single entity. Further clarification was sought but not received, so this study was counted as 200 hernias, 100 in each group. The study also included three patients with recurrent inguinal hernias, one in the polypropylene group and two in the HDPE gruop. Primary outcomes were

infection, seroma, recurrence and explantantion. Follow up was only 6 months which impacts the validity of recurrence as an outcome.

Pradhan and Pangi conducted an RCT with 60 patients, allocated purportedly equally to the intervention group, a mosquito net mesh of polypropylene/polyethylene co-polymer and the control polypropylene group.[185] However, the study reported conflicting figures for group allocations. Based on the demographic data available, it appears that 29 patients were allocated to the intervention and 31 to the control. It was not clear whether blinding of patients or assessors was undertaken. Patients with bilateral hernias were included in the study but it is not clear how these patients were treated. Patients aged less than 18 or more than 60 years old, with recurrent hernia or with immunocompromise were excluded. The only outcome measured was infection and the follow up period was short, only to 10 days.

Wani et al. compared polypropylene to a polypropylene/polyethylene co-polymer mosquito net mesh in their double blind (patient and assessor) RCT with 100 patients.[184] Each arm had 50 patients. Exclusion criteria were ASA score > 3, coagulopathy, recurrent or complex inguinal hernias and femoral hernias. Patients with bilateral hernias were included in the study but only the more symptomatic side was operated on. Outcomes were infection, seroma, haematoma, postoperative neuralgia, recurrence and length of stay. Follow up duration was 2 years.

Description of excluded articles

A number of notable articles excluded after full text review included the interim report by Ekdahl et al.[190] on the study conducted by Löfgren et al. and the non-randomised trial conducted by Goel et al. who compared polyethylene mosquito net against polypropylene mesh.[191] Attempts to contact Vasil'ev et al. and Musaev et al. for a copy of their published manuscripts were unsuccessful, so these non-English language articles were unable to be assessed for inclusion.[192,193] The abstracts of these articles did not include mention of low cost mesh. Details of the excluded articles are recorded in Table 3.

In addition, there were a significant number of observational studies and comment pieces in

the literature regarding use of low cost mesh alternatives and associated issues with this practice in LMICs.

Table 3 – Reasons for exclusion of full-text articles

Author	Year	Reason for exclusion
Ekdahl	2014	Interim data from Löfgren 2016 publication
Goel	2014	Not RCT
Herfarth	2000	Translated from German - editorial/comment on paper
Horharin	2006	Not randomised
Kamath	2019	Poster – basic literature review
Kiss	2012	Not RCT
Koziel	2015	Not RCT
Musaev	2013	Author contacted re: article; unable to access
Oribabor	2015	Not RCT
Rouet	2018	Not RCT
Skach	2019	Translated from Czech - not RCT
Smeds	2008	Translated from Swedish - not RCT
Tang	2010	Rutkow vs preperitoneal repair, not comparing mesh type
Udo	2018	Not RCT
Udwadia	2007	Letter to the editor
Vasil'ev	2007	Author contacted re: article; unable to access
Wilhelm	2007	Animal model
Yakovlev	2009	Review article
Yang	2011	Literature review
Yenli	2017	Not RCT

Methodological quality of included studies

The risk of bias the 11 included studies was assessed using the Cochrane Risk of Bias 2 (RoB2) tool.[194] These studies were appraised by two independent reviewers (AV and ZM or THB) and discrepancies resolved through discussion. In keeping with the published protocol, all studies were randomised controlled trials and none were excluded based on their RoB2 scores. The findings are presented in a Summary of Findings table created using GradePRO GDT[195] and the complete RoB2 outcomes are presented in Figure 3 and Table 3.

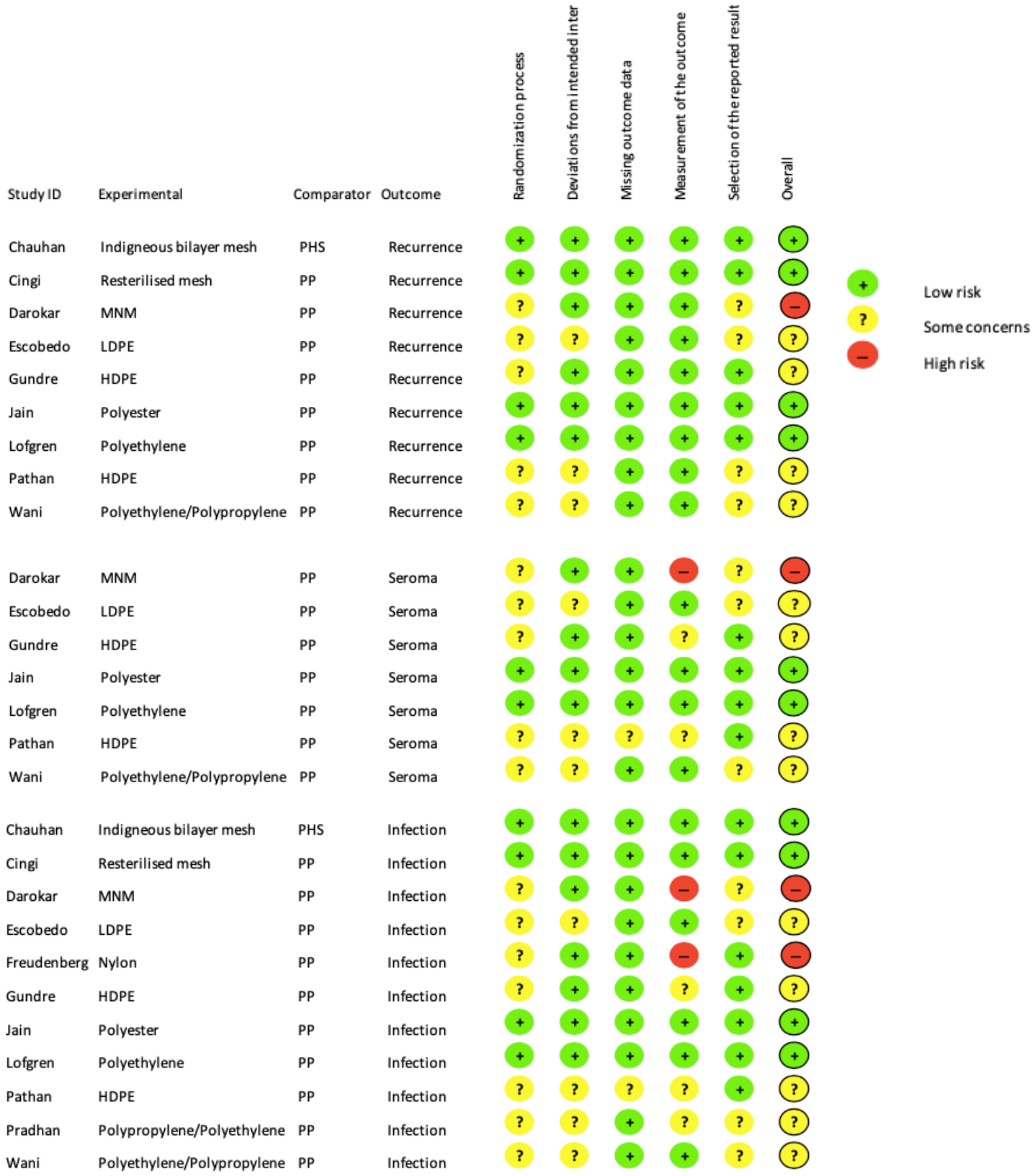
Overall, studies varied in scoring, with four studies returning overall risk of bias scores of "low" for all outcomes[180,182,186,188], five studies returning overall risk of bias scores of "some concerns" for all outcomes[181,183-185,187] and two studies returning predominantly "high" risk of bias scores for measured outcomes.[106,109] Randomisation across most studies was not

well documented, with four studies simply stating randomisation had occurred or that the study was randomised (equivalent to a “No Information” result for the RoB2 score).[106,109,183,185] Allocation concealment was also poorly documented, even with studies that had adequately described methods of randomisation.[182,184] Five studies did not describe the method of concealment at all.[106,109,183,185,187] Similarly, of the 11 studies, three did not provide adequate description to confidently assess whether blinding of patients, care providers or assessors took place.[106,183,185] One study was patient-blinded.[181] One study was assessor-blinded.[186] For those studies describing double blinding[109,180,182,184,187,188], five studies documented blinding of patient and assessor[109,182,184,187,188] and one study documented surgeon and assessor blinding.[180] However, Chauhan et al. utilised a mesh product that required construction intraoperatively and it is difficult to know how blinding of the surgeon would have been possible[180]; it was inferred that the healthcare team providing immediate postoperative care were not informed about group allocation. The summarised RoB2 assessments and associated comments are included in Appendix 3.

Table 4. Tabulated Cochrane Risk of Bias 2 outcomes for included studies

Study ID	Experimental	Comparator	Outcome	Randomization process	Deviations from intended inter	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Cingi	Resterilised mesh	PP	Cost	+	+	+	−	?	+
Escobedo	LDPE	PP	Cost	?	?	+	+	?	?
Freudenberg	Nylon	PP	Cost	?	+	+	−	+	?
Gundre	HDPE	PP	Cost	?	+	+	+	+	?
Jain	Polyester	PP	Cost	+	+	+	+	+	+
Pathan	HDPE	PP	Cost	?	?	?	?	?	?
Cingi	Resterilised mesh	PP	Explantation	+	+	+	+	+	+
Darokar	MNM	PP	Explantation	?	+	+	+	?	?
Escobedo	LDPE	PP	Explantation	?	?	+	+	?	?
Freudenberg	Nylon	PP	Explantation	?	+	+	+	+	−
Gundre	HDPE	PP	Explantation	?	+	+	?	+	?
Pathan	HDPE	PP	Explantation	?	?	+	?	?	?
Chauhan	Indigneous bilayer mesh	PHS	Haematoma	+	+	+	+	+	+
Cingi	Resterilised mesh	PP	Haematoma	+	+	+	+	+	+
Darokar	MNM	PP	Haematoma	?	+	+	−	?	−
Jain	Polyester	PP	Haematoma	+	+	+	+	+	+
Lofgren	Polyethylene	PP	Haematoma	+	+	+	+	+	+
Wani	Polyethylene/Polypropylene	PP	Haematoma	?	?	+	+	?	?
Chauhan	Indigenous bilayer mesh	PHS	Pain	+	+	+	+	+	+
Escobedo	LDPE	PP	Pain	?	?	+	+	?	?
Freudenberg	Nylon	PP	Pain	?	+	+	−	+	?
Jain	Polyester	PP	Pain	+	+	+	+	+	+
Lofgren	Polyethylene	PP	Pain	+	+	+	+	+	+

+ Low risk
? Some concerns
− High risk


Study ID
Experimental
Comparator
Outcome
Randomization process
Deviations from intended inter
Missing outcome data
Measurement of the outcome
Selection of the reported result
Overall
Chauhan Indigneous bilayer mesh PHS Recurrence
Cingi Resterilised mesh PP Recurrence
Darokar MNM PP Recurrence
Escobedo LDPE PP Recurrence
Gundre HDPE PP Recurrence
Jain Polyester PP Recurrence
Lofgren Polyethylene PP Recurrence
Pathan HDPE PP Recurrence
Wani Polyethylene/Polypropylene PP Recurrence
Darokar MNM PP Seroma
Escobedo LDPE PP Seroma
Gundre HDPE PP Seroma
Jain Polyester PP Seroma
Lofgren Polyethylene PP Seroma
Pathan HDPE PP Seroma
Wani Polyethylene/Polypropylene PP Seroma
Chauhan Indigneous bilayer mesh PHS Infection
Cingi Resterilised mesh PP Infection
Darokar MNM PP Infection
Escobedo LDPE PP Infection
Freudenberg Nylon PP Infection
Gundre HDPE PP Infection
Jain Polyester PP Infection
Lofgren Polyethylene PP Infection
Pathan HDPE PP Infection
Pradhan Polypropylene/Polyethylene PP Infection
Wani Polyethylene/Polypropylene PP Infection
Low risk
Some concerns
High risk

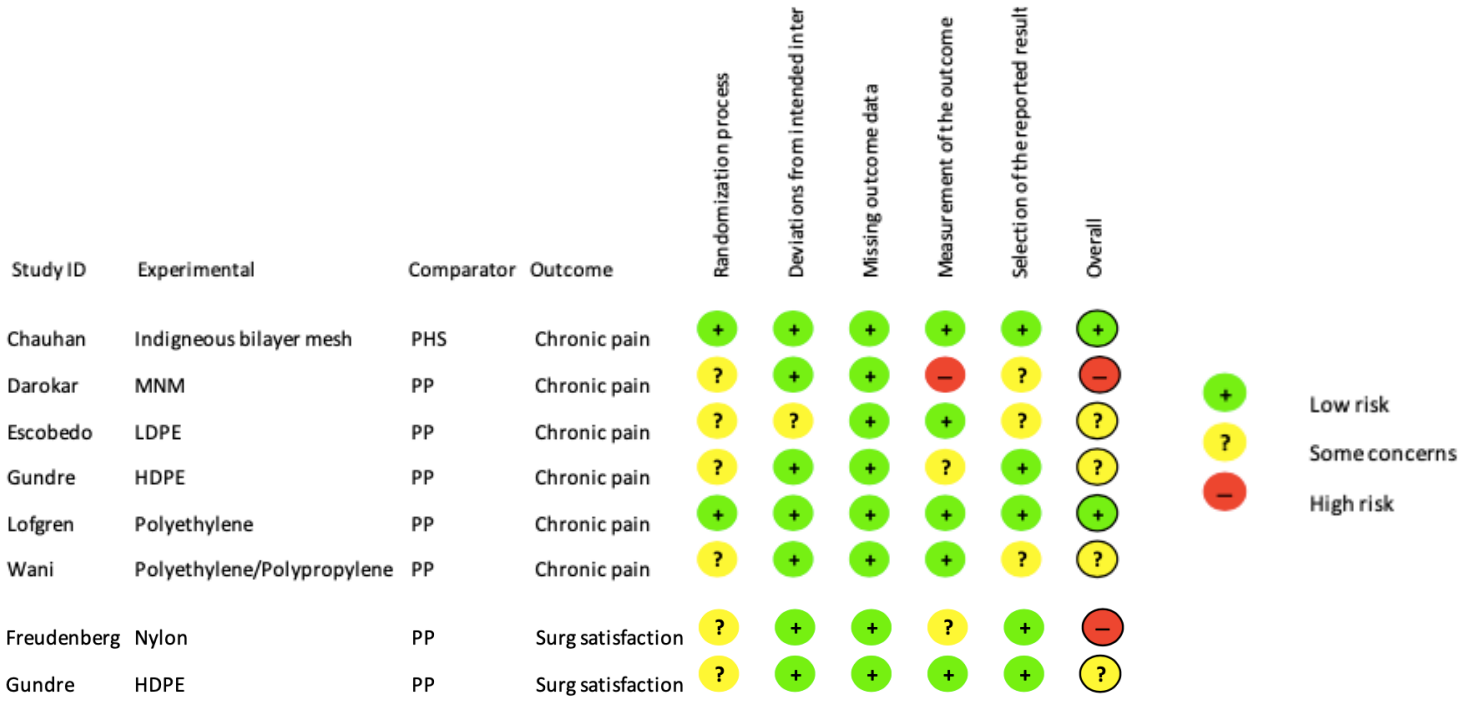
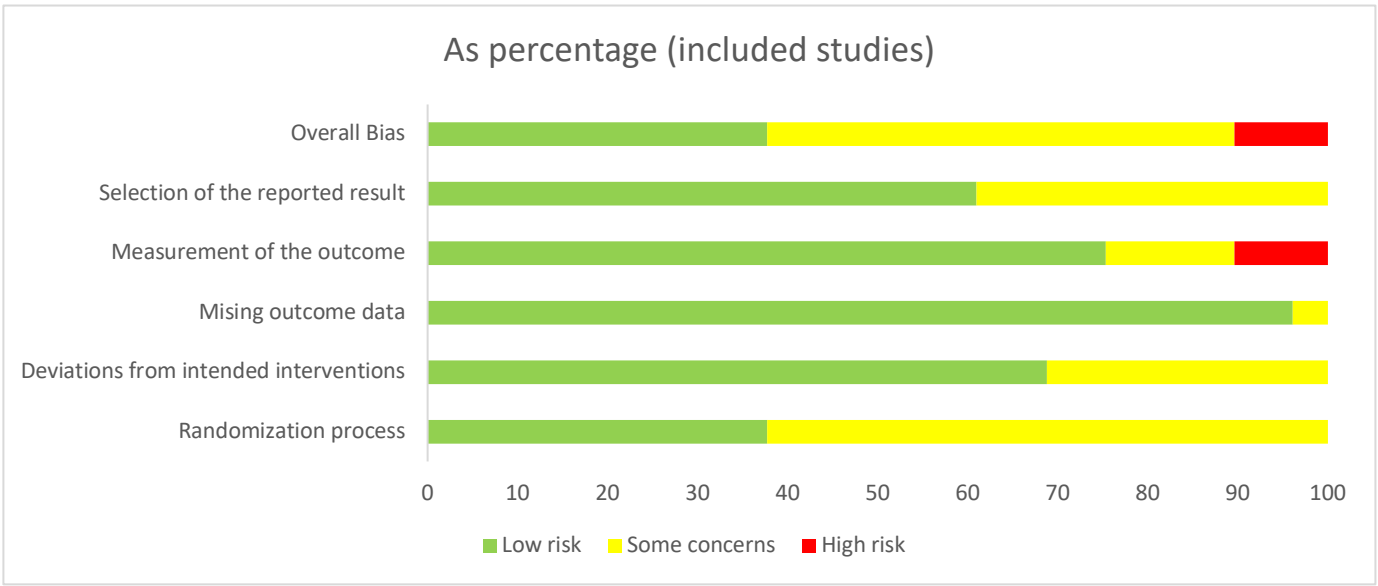


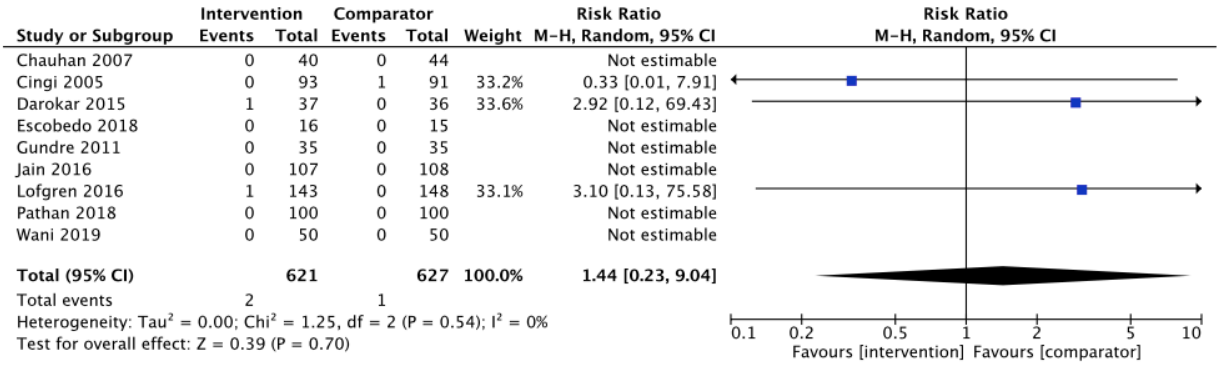
Figure 3. Graphical Cochrane Risk of Bias 2 outcomes for included studies



Findings of the review

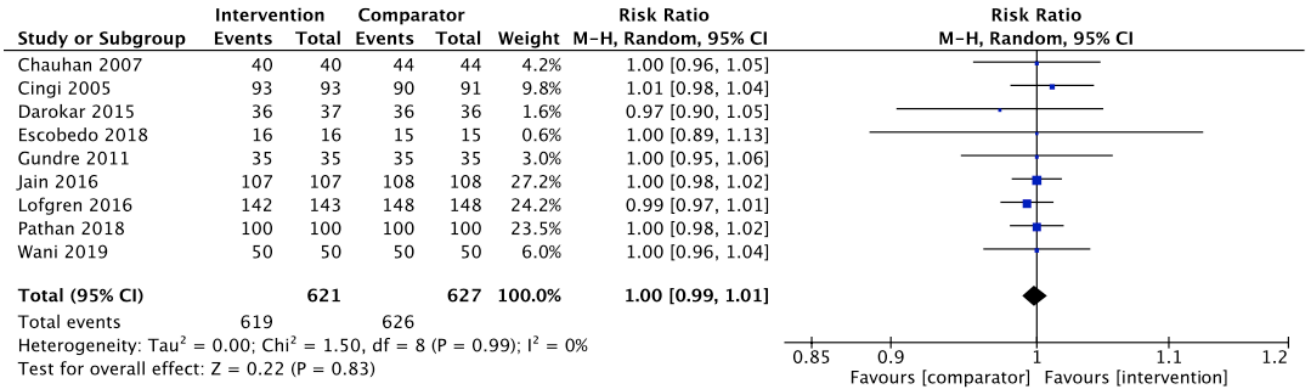
Recurrence

Figure 4. Forest plot of comparison, low cost mesh vs surgical mesh, recurrence



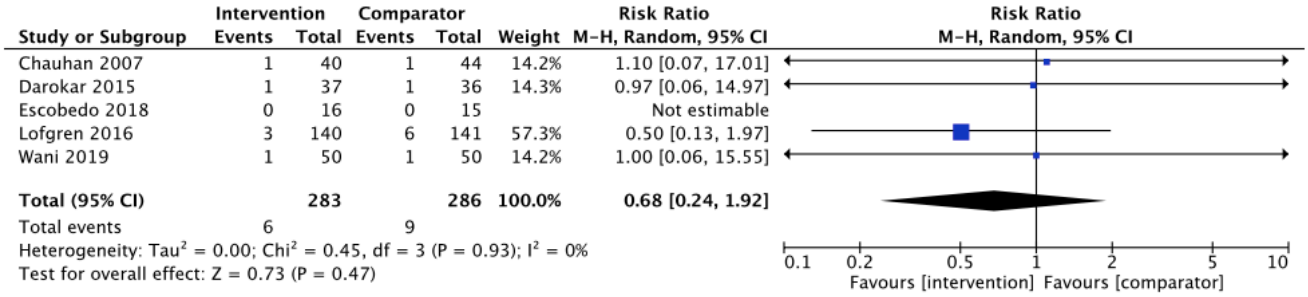
Recurrence was recorded as an outcome by 9 studies with a total of 1248 patients and 3 events (3/1248 = 0.24%).[106,180-184,186-188] There was little to no evidence of an effect of low cost mesh compared with surgical mesh on recurrence (RR 1.44, 95CI: 0.23 to 9.04, p = 0.70). This was an imprecise finding showing recurrence to be higher in the intervention group. There was no heterogeneity observed, probably due to the very wide confidence intervals for the individual study effects. Tests for heterogeneity indicated low heterogeneity with $\tau^2 = 0$, χ^2 p-value of 0.54 and $I^2 = 0\%$. Due to the low event rate, a sensitivity analysis with non-events is presented demonstrating no difference between low cost and surgical mesh (RR 1, 95CI: 0.99 to 1.01, p = 0.83).

Figure 5. Forest plot of comparison, low cost mesh vs surgical mesh, recurrence (non-event)



Chronic Pain

Figure 6. Forest plot of comparison, low cost mesh vs surgical mesh, chronic pain



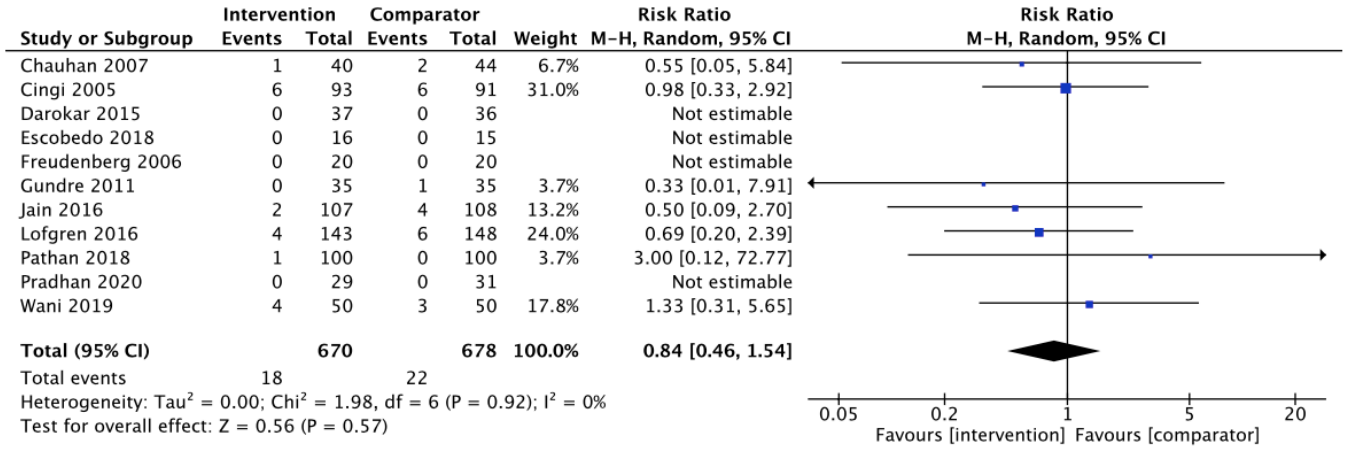
Five studies recorded postoperative pain after hernioplasty utilising low cost mesh alternatives. Chauhan et al., Darokar et al., Escobedo et al. and Wani et al all reported chronic pain or inguinodynia as primary outcomes without explicit definition[106,180,184,187] and Löfgren et al. reported IPQ scores.[188] There was little to no evidence of an effect of low cost mesh compared to surgical mesh on chronic pain (RR 0.68, 95CI: 0.24 to 1.92, p = 0.47).This was an imprecise finding showing chronic pain being lower in the intervention group. There was no heterogeneity observed, probably due to the very wide confidence intervals for the individual study estimates. Tests for heterogeneity indicated low heterogeneity with $\tau^2 = 0$, χ^2 p-value of 0.93 and I^2 of 0%.

For the study conducted by Löfgren et al., an IPQ score of 4-5, that is pain interfering with daily activities was used to define chronic pain, in keeping with international guidelines.[134,188]

Chauhan et al. had follow up 3 monthly postoperatively, Darokar et al. at 1, 6 and 12 months, Escobedo et al. at 3 and 6 months and Wani et al. at 2 months, 6 months, 12 months and Löfgren et al. assessed IPQ at 12 months.[106,180,184,187,188]

Superficial infection

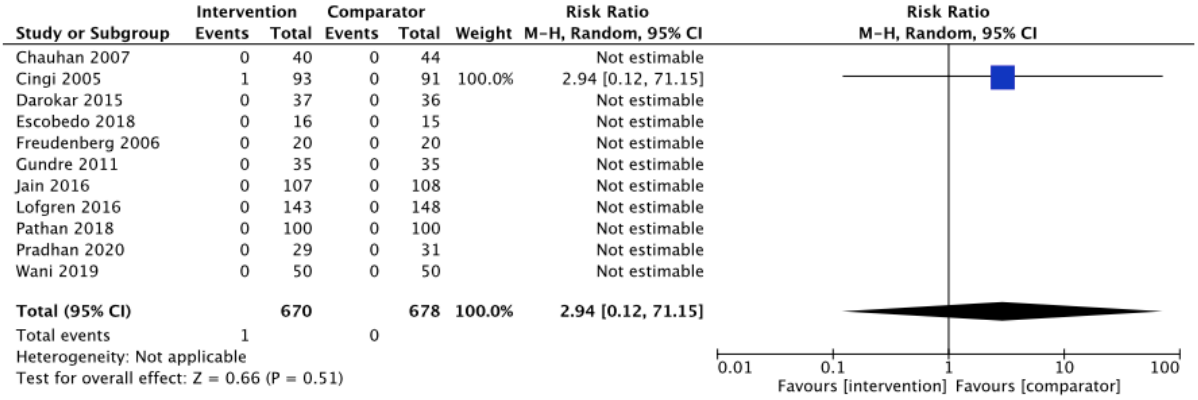
Figure 7. Forest plot of comparison, low cost mesh vs surgical mesh, superficial infection



All studies included in the review reported on superficial infection with 1348 patients included, albeit with varying detail provided on what constitutes superficial infection. There was little to no evidence of an effect of low cost mesh compared to surgical mesh on superficial infection (RR 0.84, 95CI 0.46 to 01.54, p = 0.57). This was an imprecise finding showing superficial infection being lower in the intervention group. There was no heterogeneity observed, probably due to the very wide confidence intervals for the individual study estimates. Tests for heterogeneity indicated low heterogeneity, with $\tau^2 = 0$, χ^2 with a p-value of 0.64 and $I^2 = 0\%$.

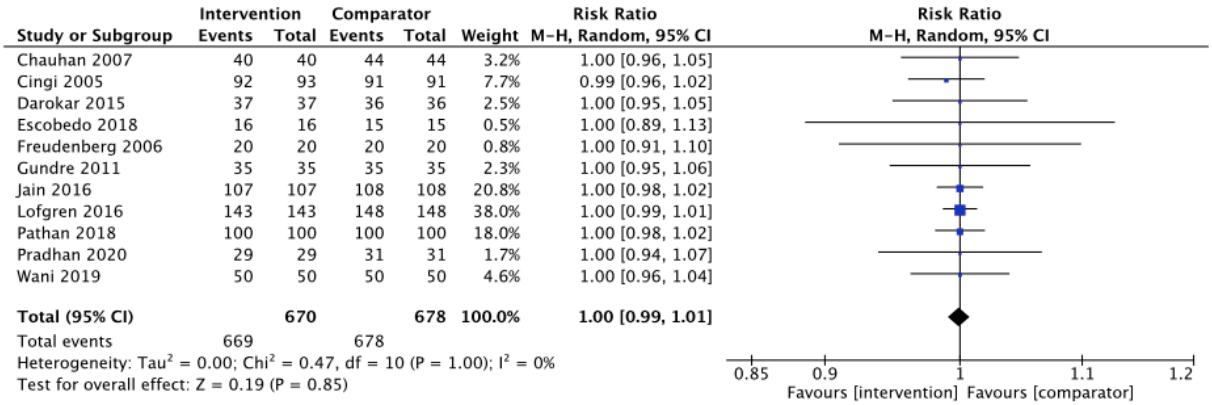
Deep infection

Figure 8. Forest plot of comparison, low cost mesh vs surgical mesh, deep infection



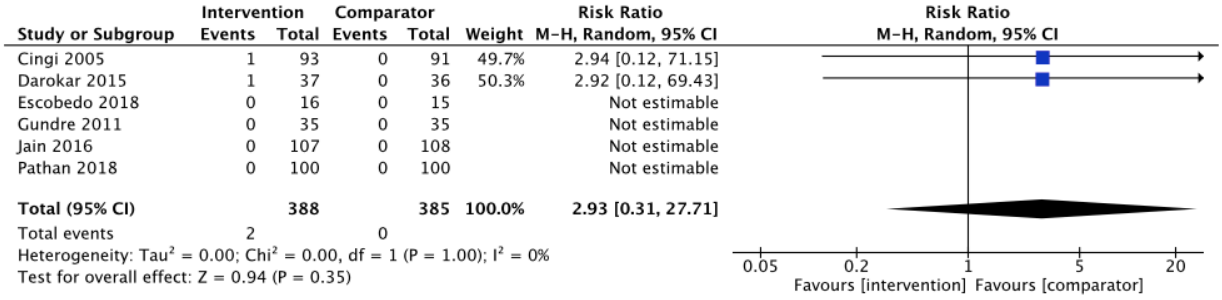
All included studies reported on deep infection.[106,109,180-188] Event rates were low such that deep infection was only reported once, by Cingi et al., in the low cost mesh group.[186] Meta-analysis in this setting was not useful and the non-event sensitivity analysis is also presented.

Figure 9. Forest plot of comparison, low cost mesh vs surgical mesh, deep infection (non-event)



Explantation

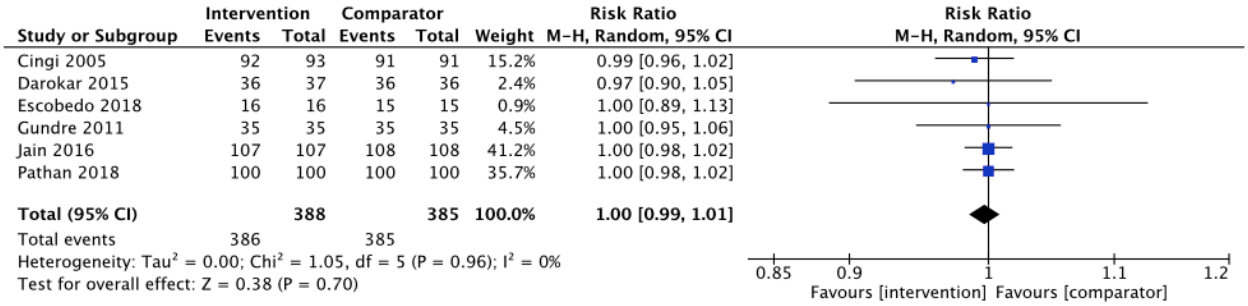
Figure 10. Forest plot of comparison, low cost mesh vs surgical mesh, explantation



Explantation or removal of mesh was recorded as an outcome in 6 studies, with a total of 598 patients.[106,181-183,186,187] There was little to no evidence of an effect of low cost mesh compared with surgical mesh on explantation (RR 2.93, 95CI: 0.31 to 27.71, p = 0.35). This was a very imprecise finding showing explantation to be higher in the intervention group. There was no heterogeneity observed, probably due to the wide confidence intervals for the individual study estimates. Tests for heterogeneity indicated low heterogeneity with $\tau^2 = 0$, χ^2 p-value = 1 and $I^2 = 0\%$.

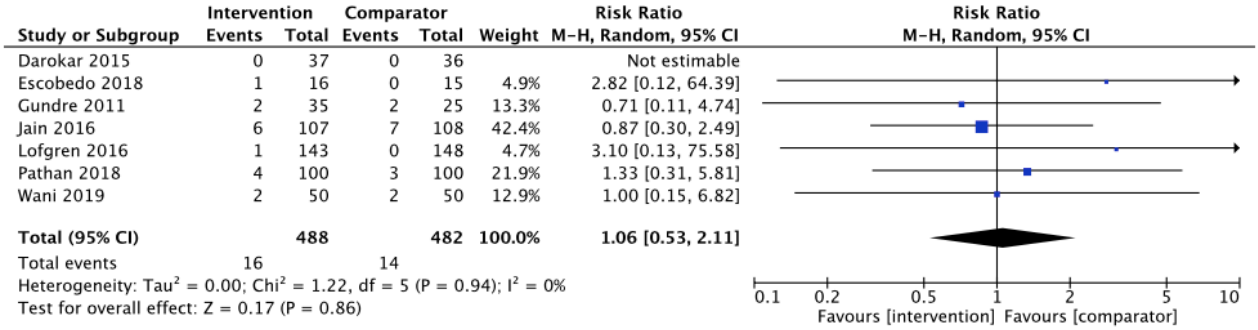
Due to the low number of events, a non-event sensitivity analysis was conducted and this indicated no difference between surgical mesh and low cost mesh with regards to explantation (RR 1, 95CI: 0.99 to 1.01, p = 0.70).

Figure 11. Forest plot of comparison, low cost mesh vs surgical mesh, explantation (non-event)



Seroma

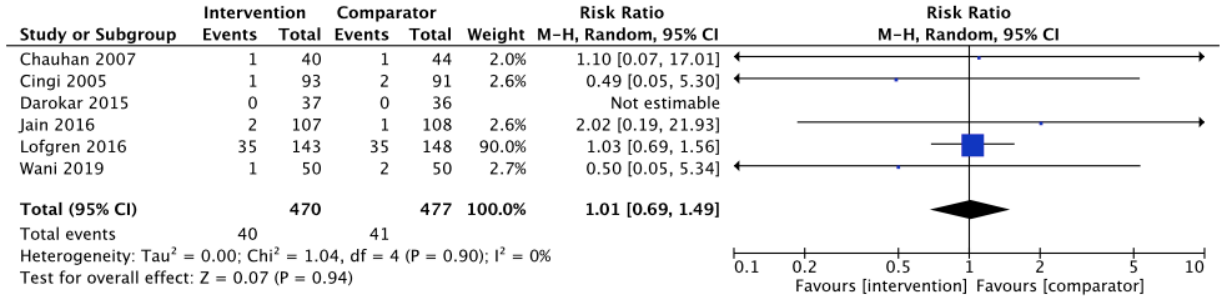
Figure 12. Forest plot of comparison, low cost mesh vs surgical mesh, seroma



Seven studies recorded incidence of seroma with a total of 970 patients and 30 events.[106,181-184,187,188] There was little to no evidence of an effect of low cost mesh compared to surgical mesh on seroma (RR 1.06, 95CI: 0.53 to 2.11, p = 0.86). This was an imprecise finding showing seroma being higher in the intervention group. There was no heterogeneity observed, probably due to the very wide confidence intervals for the individual study effects. Tests for heterogeneity indicated low heterogeneity with $\tau^2 = 0$, χ^2 p-value = 0.94 and $I^2 = 0\%$.

Haematoma

Figure 13. Forest plot of comparison, low cost mesh vs surgical mesh, haematoma

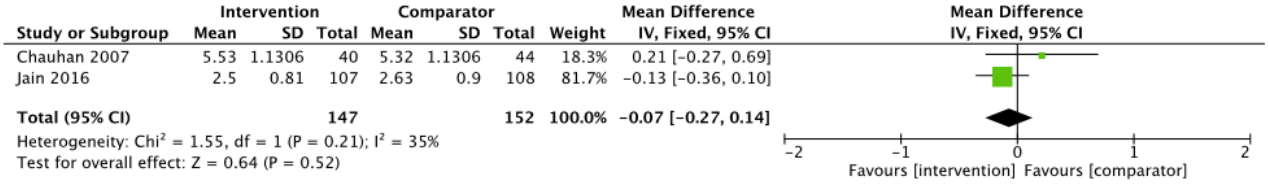


Haematoma was recorded as an outcome by six studies, with a total of 943 patients and 81 events. [106,180,186] [182,184,188] There was little to no evidence of an effect of low cost mesh compared to surgical mesh on haematoma (RR 1.01, 95CI: 0.69 to 1.49, p = 0.94). This was an imprecise finding showing haematoma to be higher in the intervention group. There was no heterogeneity observed, probably due to the very wide confidence intervals for the individual study effects. Tests for heterogeneity indicated low heterogeneity with $\tau^2 = 0$, χ^2 p-value = 0.90 and $I^2 = 0\%$.

Löfgren et al. had significantly higher incidence overall than the other studies (LCM 35/143 = 24.48%, surgical mesh 35/148 = 23.65%)[188] and a sensitivity analysis was performed. This did not alter the outcome (RR 0.84, 95CI: 0.25 to 2.88, p = 0.79).

Postoperative pain

Figure 14. Forest plot of comparison, low cost mesh vs surgical mesh, postoperative pain



Chauhan et al. and Jain et al. both recorded pain scores in the immediate postoperative period, comparing surgical mesh with low cost mesh at day 1 postoperatively.[180,182] Both used the visual analogue scale (results reported from 0-10). Chauhan et al. did not provide a standard deviation but did provide a p-value and this was used to impute a standard deviation following guidance and using the calculator function on RevMan.[180] The findings were rechecked for accuracy using the online calculator at stattrek.com.[196] There was little to no evidence of an effect of low cost mesh compared to surgical mesh on postoperative pain (MD = -0.07, 95CI: -0.27 to 0.14, p = 0.52). Tests for heterogeneity were mixed with non-significant χ^2 (p-value = 0.21) but I^2 = 35%, indicating a moderate level of heterogeneity.

Studies not included in the meta-analysis

A number of studies recorded pain at different timepoints but were not able to be included in the meta-analysis due to 1) no comparator study – Jain et al. at 6 hours, Gundre et al. at 12 hours, Löfgren et al. at 12 months[181,182,188] and 2) no standard deviation or p-value given to facilitate imputation (Freudenberg et al. preoperatively and Escobedo et al. at all timepoints).[109,187]

Escobedo et al. recorded similar pain scores on the Visual Analogue Scale (VAS) for low cost and surgical mesh at all time points, reducing over time (mean score: 4.7 for LCM and 4.6 for surgical mesh at 1 week and 0.1 and 0.3 respectively at 6 months).[187] Löfgren et al. had very similar pain scores measured on the Inguinal Pain Questionnaire (IPQ), which also

reduced over time (mean score, SD: 3.4±1.3 for LCM and 3.4±1.2 for surgical mesh preoperatively, 1.3±0.7 at 12 months for both).[188] Freudenberg et al. utilised a modified Standard Multidimensional Questionnaire (SF36)[197], the Ouagadougou Life Quality Index (OLQUI), measured preoperatively and at 30 days post procedure with 0 being maximal pain and 10 being minimal pain.[109] Scores on this scale were recorded as frequencies, with most patients scoring 9 (range 0-10) in the low cost mesh group preoperatively and 10 (range 5-10) postoperatively; in the comparison group preoperative and postoperative pain was rated as 10 (preoperative range 3-10, postoperative range 7-10).[109]

Patient satisfaction

Patient satisfaction was recorded by Freudenberg et al. preoperatively and at 1 month postoperatively using the OLQI with no significant difference between mesh at either timepoint.[109] Löfgren et al. assessed patient satisfaction with a yes/no questionnaire at 12 months.[188] Gundre et al. reported 33/35 patients in the surgical mesh and 32/35 patients in the low cost mesh group were satisfied with scar quality with no statistically significant difference between groups.[181] This data was not suitable for meta-analysis.

Surgeon satisfaction

Freudenberg et al. recorded surgeon satisfaction on a simple 3 point scale, “not practical”, “practical” and “very practical”.[109] Both low cost mesh and surgical mesh were judged “very practical” with no difficulties in handling.

No other studies included data about surgeon satisfaction using low cost mesh and therefore this outcome was not suitable for meta-analysis.

Durability of mesh

Cingi et al. conducted mechanical strength testing of resterilised mesh prior to its use in their RCT.[186] The surgical mesh was manipulated, sterilised and then tested for tensile strength, mechanical deformation compared against surgical mesh. Resterilised mesh (the intervention) had an average tensile strength of 58.2±2.9 N/m compared with 66.6±3.7 N/m for the surgical mesh (control) along length of mesh, and 32.3±0.8 N/m vs 28.7±5.1 N/m along width. Maximum extension at maximum load along length was 144.4±3.8% for the

intervention and 110.8±10.7% for the control mesh and 117.2±3.9% vs 120.2±22.9% along width respectively.

No other studies included data about durability of low cost mesh on a mechanical basis and therefore this outcome was not suitable for meta-analysis. Pathan et al., however, did comment that steam autoclaves do not exceed 132°C as part of the sterilisation cycle.[183] They commented that in light of the HDPE mosquito net mesh used having a melting temperature of 144-159°C, this should not impact on the size or pliability of the material after sterilisation.[183]

Sterility of mesh

Cingi et al. tested sterility of the low cost mesh (resterilised polypropylene) used in their RCT.[186] Prolene mesh was manipulated, resized, repackaged and resterilised by steam autoclave at 121°C for 20 minutes and then cultured in aerobic and anaerobic media. The comparator mesh was also cultured in the same media. All cultures were negative at all time points up to 30 days post-sterilisation.

No other studies included data about sterility of low cost mesh on a histological or microbiological basis and therefore this outcome was not suitable for meta-analysis.

Cost

Ten studies reported cost as an outcome.[106,109,180-184,186-188] Of these, eight recorded only cost of the intervention low cost mesh against the cost of surgical mesh used[106,109,180,181,183,186-188], one study compared total cost of surgery, including mesh and disposable products of the two groups[182] and one study only recorded cost of the comparator product (surgical mesh).[184] The results are presented in Table 5.

No studies included an analysis of cost encompassing purchase price of low cost mesh and staff time and equipment required for sterilisation and packaging compared against surgical mesh. Therefore, this outcome was not suitable to be analysed using meta-analysis.

Table 5. Comparison of low cost mesh vs surgical mesh

Study details		**Cost**		
Author / Year	Currency	Intervention	Comparator	Cost ratio
Chauhan 2007	INR	600	8000	13.33
Cingi 2005	USD	27.9	58.5	2.10
Darokar 2015	INR	40	1958	48.95
Escobedo 2018	MXN	5	2500	500.00
Freudenberg 2006	USD	0.0043	108	25116.28
Gundre 2011	INR	0.563	1580	2806.39[a]
Jain 2016	INR	605	1700	2.81[b]
Löfgren 2016	USD	0.01	125	12500.00
Pathan 2018	INR	3.94	1800	456.85
Wani 2019	INR	0.45	1666	3702.22

a. Ratio calculated for 7/5x15cm mesh; 2808.89 for larger 15x15cm
b. Cost of disposables and mesh

Chapter 4: Discussion

The use of low cost mesh in hernioplasty in low and middle income countries is an established practice and builds on a long history of innovative surgical practice driven by limited resources, ranging from the development of the Bogota bag to use of nylon fishing line as suture material.[198] This systematic review and meta-analysis identified 11 randomised controlled trials conducted within the last 20 years comparing low cost mesh to surgical mesh.[106,109,180-188] Overall, there was little to no evidence of an effect of low-cost mesh compared with surgical mesh on the studied outcomes. However, a number of outcomes lacked sufficient data to facilitate meta-analysis. In addition, methodological concerns, inadequate detail provided by study authors about patient and outcome data and varying definitions of outcomes limited ability to compare across studies confidently and easily. Limitations of the review, implications of the results for practice and finally, implications and scope for further research into the area will be detailed.

This systematic review and meta-analysis is the fifth assessment of the literature regarding use of low cost mesh in hernioplasty. It is the third systematic review in the last five years. Patterson et al. conducted a systematic review and meta-analysis of the RCTs assessing postoperative adverse effects of mosquito net mesh hernioplasty in low income countries.[138] The search for this review was conducted in September 2016 across PubMed, Ovid EMBASE/MEDLINE, Web of Science and Cochrane Library. Citation searching was performed using Google Scholar and trial registries searched. The search strategy was limited to “hernia”, “mosquito”, and “mosquito nets”. Patterson et al. identified five RCTs with a total of 620 patients. Of these five RCTs, four studies considered inguinal hernia[106,109,181,188] and one study, incisional hernia.[199]. This review concluded that adverse event rate was not significantly different between either groups and supported the equivocal efficacy and safety profile of mosquito net mesh in hernioplasty.

The systematic review and meta-analysis conducted by Ahmad et al.[86] included RCTs, non-randomised controlled trails and observational studies considering the use of mosquito net mesh in humans. Searches were conducted across PubMed/MEDLINE, Embase and the Cochrane Central Register of Controlled Trials until August 2018. Citation searching of

relevant studies was performed. Nine studies in total were identified.[99,109,110,112,180,188,200-202] Of these, four studies, three RCTs[109,180,188] and one non-RCT[200], were included in the meta-analysis, for a total of 1360 patients. The primary outcome was overall complication rate and the secondary outcomes, wound infection, chronic pain and haematoma formation. The review found that little to no evidence of an effect of low cost mesh compared with surgical mesh across these outcomes but concluded that long-term performance and a larger body of evidence was required before recommendations can be made.[86]

This current systematic review identified a number of observational studies, editorials and comments regarding the use of low-cost mesh in hernioplasty in addition to the included RCTs. These articles are discussed in relation to the outcomes assessed in this review.

Postoperative pain

Postoperative pain can be immediate or chronic and chronic pain is a clinically significant and frequent complication of hernioplasty.[8,134] The definition of chronic postoperative inguinal pain (CPIP) varies in the literature and is not consistently applied.[134,203] Pain is also frequently measured on various scales by different authors, with only some of the scales used validated.[203,204] The current HerniaSurge definition of chronic pain is the presence of pain from three months postoperatively, rated as greater than moderate by the patient and impacting on daily activities.[12]

Our meta-analysis showed a relative risk of RR 0.68 (0.24-1.92; low certainty) for chronic pain using low cost mesh. This was an imprecise finding and the risk difference ranged between 24 fewer to 29 higher cases per 1000. There was little to no evidence of an effect ($p = 0.47$). This is not a clinically significant finding as the point estimate and range of incidence of chronic pain in the low cost mesh group (2.1%; 6/283; 0.7-6%) falls within the wide range of estimates for CPIP in the literature.[134]

The variation in descriptors, definition and measurement of chronic pain identified in the literature was reflected in the five studies included in this review with chronic pain as an outcome. Three different descriptors, chronic inguinodynia[187], postoperative neuralgia[180] and chronic pain[106,184,188] were used by the study authors and further definition of these was

absent in four studies[106,180,184,187]. Löfgren et al. used the Inguinal Pain Questionnaire (IPQ), a validated tool developed for assessment of CPIP[205] at 12 months postoperatively and recorded the impact on quality of life.[188] Details regarding the timepoint, method of assessment and use of an instrument or tool during this assessment of chronic pain were lacking in the remaining four studies. However, these studies included follow up appointments at least three months postoperatively[106,180,184,187], so would have satisfied the minimum time requirements for the HerniaSurge definition of CPIP.[12] Of the included studies, only Löfgren et al. recorded a preoperative pain score, despite this being a known risk factor for development of chronic pain.[133,188,206,207] Chauhan et al. used the PHS repair technique rather than Lichtenstein repair.[180] While systematic reviews have demonstrated comparable outcomes with regards to chronic pain for both techniques[48,208], this does introduce a potential confounder into the dataset.

There are numerous factors that impact on chronic pain but pertinent to use of low cost mesh in LMICs are mesh material, weight of mesh, preoperative pain, patient age and operator experience.[133,206,207]

Mesh material and composition is a known component in the extent of foreign body reaction[12,63] and foreign body reaction is a contributing factor to the development of CPIP.[133] Animal models have demonstrated a significantly greater inflammatory reaction with mosquito net mesh than surgical mesh but this did not correlate to a difference clinical outcomes.[78,209] Many of the materials used in low cost mesh, such as polyester, polyethylene and nylon, have also previously been used in surgical mesh products.[13] Combined with the findings of this review, the use of low cost mesh alternatives appears to be safe with regards to chronic pain.

Weight of mesh has been hypothesised to impact on rates of chronic pain and this question has been assessed through a number of systematic reviews and meta-analyses.[34,56,57,210] Within limitations, these reviews have found that lightweight mesh reduces chronic pain[34,56,57,210] but this effect is not present for severe pain.[210] Foreign body sensation is reduced with use of lightweight mesh.[34,56,57,210] Three studies reported use of lightweight mesh[180,187,188] while the others did not state this explicitly. The minimum information

obtained about low cost mesh prior to implantation should include its weight and lightweight products should be used preferentially.

Of the included studies, only Löfgren et al. recorded a preoperative pain score, despite this being a known risk factor for development of chronic pain.[133,206,207] The high prevalence of inguinal hernia in LMICs[94,103,211] would suggest that rates of preoperative pain are also high, as two thirds of patients are symptomatic and longer duration of hernia presence increases the probability of pain.[212] Recording preoperative pain scores as routine would be beneficial in future studies, both to assess prevalence of pain in LMICs and to generate a baseline to compare against postoperatively.

Men with inguinal hernia in LMICs are younger than men in HICs.[68,96] In Africa, the highest prevalence is in men 20-40 years old[94,103,213] while it is higher in India, occurring in men 30-60 years old.[214-218] Younger age is a known risk factor for CPIP.[133,206,207] The mean age of patients in this review ranged between 35-56 years old, which is representative of the population profiles of India but slightly older than the typical African patient. This may reflect the large number of studies from India in this review[106,180-185] but even the two African studies had mean ages of 35 and 45 years.[109,188] This may indicate difficulty recruiting younger men to the trials but the findings are still representative of and relevant for, LMICs.

Finally, CPIP is impacted on significantly by the operator experience.[207,219] All studies in this review used qualified general surgeons. [106,180,186 109,181-185,187,188] This is not representative of the surgical workforce of most LMICs, where services are often provided by medical officers or non-medically qualified health workers.[220-223] However, training of non-surgeons has been shown to deliver similar outcomes to trained surgeons within selected populations.[80,224,225] The impact of non-surgeons on chronic pain can be mitigated and the findings of this review are generalisable. The lack of clear definition of chronic pain and identification of timepoints of measurement limited the ability to confidently compare across studies. Future studies should aim to use a standard instrument to measure pain (such as the VAS or IPQ) at standard timepoints, including preoperatively, at 3 and 12 months to facilitate diagnosis of chronic pain.

Acute postoperative pain is multifactorial in aetiology and impacted on by patient, health professional and operative factors.[226,227] Personal pain history and psychosocial factors play a significant role in patient experiences of pain.[228,229] Anaesthesia type and delivery, institutional pain protocols and effective pharmacotherapy to manage postoperative pain also affect outcomes.[230-233] Finally, anaesthetic provider and surgeon operator experience[234] and operative technique[235,236] also affect acute postoperative pain.

In total, two studies with 199 patients recorded pain day one postoperatively using the visual analogue scale (VAS).[180,182] Our meta-analysis showed a mean difference of MD 0.07 lower (0.27 lower to 0.14 higher; high certainty). These results indicate there is no meaningful difference in terms of acute postoperative pain between groups, as even if the result was significant, a reduction of 0.07 on the VAS is not reported as a clinically meaningful difference. Other studies that did not contribute data to the meta-analysis did not show a convincing or important difference in pain scores.

All patients in the Jain et al. trial received spinal anaesthesia whereas the majority of patients enrolled by Chauhan et al. received local anaesthesia only (72/84 = 85.7%).[180,182] There is evidence that early postoperative pain is reduced using LA but there is no difference between GA, spinal or LA beyond 1 week.[237] The findings of this review are still relevant despite the difference in anaesthesia given in these two studies.

The elective repair of inguinal hernia under LA in LMICs is limited by intraoperative discomfort[231], provider unfamiliarity[234] and repair of larger hernias, often inguinoscrotal, requiring GA or spinal anaesthesia.[72] Surgeons in LMICs also report less consistent analgesic results with use of LA, further reducing incentive for its use.[114] In addition, LMICs have higher rates of emergent presentation and this can require general anaesthesia to facilitate bowel resection and repair.[119] The majority of studies in this review utilised spinal anaesthesia, with only Löfgren et al. and Chauhan et al. using LA.[180,188] This is representative of the wider practice of hernia repair in LMICs[82,238] and carries an increased risk of higher early postoperative pain, alongside longer duration of stay and urinary retention.[237,239]

The included studies all used trained general surgeons[106,180,186 109,181-185,187,188] in majority urban hospitals.[106,180,186 109,181-185,187] This is not representative of the workforce or surgical caseload distribution of inguinal hernia repair in LMICs which often occurs in rural or district hospitals with non-surgeon physicians.[223,224] There is evidence that practitioner experience impacts on operating under LA in HICs[240] and LMICs.[234] Junior or training surgeons use higher volumes of LA[241] and may have higher rates of recurrence when operating under LA.[12] The risk of worse operative outcomes needs to be balanced with the advantages of inguinal hernia repair under LA in LMICs where the operating clinician may not be a general surgeon or be less experienced.

Finally, the studies included in this review considered predominantly elective inguinal hernia repairs and only Löfgren et al. commented on the inclusion of patients with inguinoscrotal hernias. Again, this is not representative of the LMIC hernia population, who often present emergently or with large inguinoscrotal hernias. The use of LA is less feasible in repair of large inguinoscrotal hernias and LA alone is not used in the emergent setting. The findings of this study with regards to acute pain and use of LA are not applicable in this context.

The postoperative pain regimen was not well described in most studies, with Darokar et al. and Löfgren et al. using non-steroidal anti-inflammatory drugs (NSAIDs) and paracetamol[106,188], Escobedo et al. and Gundre et al. only mentioning NSAIDs [181,187] and Jain et al. stating postoperative analgesics were provided.[182] The use of multi-modal analgesia has been shown to be useful in the acute postoperative context[242] and the HerniaSurge guidelines recommend use of intraoperative field blocks, wound infiltration and multimodal oral analgesia with NSAIDs and paracetamol.[12] In the context of implanting low cost mesh in LMICs, where operating clinicians will likely be more junior or not surgically qualified, maximising intraoperative and postoperative analgesia with a multi-modal approach would be beneficial in reducing acute pain and minimise risk of chronic pain.

Chauhan et al. used a low cost version of the PHS, which is different to the flat mesh used in Lichtenstein repairs.[180] While the literature demonstrates similar pain scores between Lichtenstein and PHS[48], this does introduce a potential confounder into the meta-analysis.

Of the other studies included in the review, three studies recorded postoperative pain scores within the first month but at time points that were not comparable to other studies or without sufficient detail to facilitate analysis. [109,181,187] Furthermore, Freudenberg et al. utilised a separate quality of life scale that, while based off the validated SF36, was unable to be compared to other studies.[109] Löfgren et al. reported severe pain in two patients in the low cost mesh group at the two week postoperative review but did not quantify this further and this was not included in the meta-analysis.[188] The variation in scales and timepoints of measurement limited the ability to compare across studies and future studies should aim to use a standard instrument to measure pain (such as the VAS or IPQ) and at standard timepoints, including preoperatively, 1 day postoperatively, and 1 month postoperatively for acute pain.

Infection

Wound infection in inguinal hernioplasty is a commonly reported and important outcome[12,13,116] due to the implantation of a foreign body.[33] Infection risk is influenced by surgical technique, surgeon experience, patient characteristics, operative context and the mesh construct.[12,33,50,120,243-245] When considering use of low cost mesh in LMICs, hospital and institutional factors such as sterilisation capacity, security of storage and discharge destination and follow up of patients are also important considerations. These are all potential confounders.

The studies in this review predominantly focused on unilateral primary inguinal hernias in patients with ASA < 3, although five studies included bilateral hernias[106,109,181-183,187] and two did not state how patients with bilateral hernia were treated.[180,185] There is weak evidence that bilateral inguinal hernia repair increases the risk of infection[246] although this effect may be related to an increased duration of Recurrent hernias[106,180-182,184-188] and immunocompromised patients[181,182,184,185,187] were excluded. Patient risk factors for SSI in inguinal hernia repair are debated[247] with diabetes, BMI > 35, smoking history and a National Noscomial Infection Surveillance Score of > 2 (a system comprising duration of operation, ASA score > 3 and operation status of contaminated or dirty) best supported in

the literature.[244,248] The findings of this review are best applicable to this selected group of patients, that is, patients undergoing elective repair of primary unilateral inguinal hernias.

Superficial infection was reported by all 11 studies in the review.[106,180,186 109,181-185,187,188] Our meta-analysis showed a relative risk of RR 0.84 (0.46-1.54; low certainty) for superficial infection using low cost mesh. This was an imprecise finding and the risk difference ranged from 18 fewer to 18 more cases per 1000. There was little to no evidence of an effect (p = 0.57). This is not a clinically significant finding as the point estimate and range of incidence of superficial infection in the low cost mesh group (2.7%, 18/670; 0.9-4.5%) falls within the range of estimates in the literature for superficial infection.[33,120]

However, only six studies provided a definition or grading system for what constituted superficial infection.[109,181,182,185,186,188] Cingi et al. used the National Centre for Infectious Diseases criteria[186,249], Freudenberg et al. used a three level grading system with definitions provided[109], Gundre et al. used five level grading system but provided only limited description of what these indicated[181], Löfgren et al. and Jain et al. provided a binary distinction between superficial and deep infection [182,188] and Pradhan et al. used the Southampton score.[185,250]

Studies also assessed the presence of superficial infection at different time points. The first review occurred between one day[106,180-182,186] to one month postoperatively[109] and the duration until second review ranged between two days[185] to 12 months.[188] This wide variation in timing of follow up reviews means that potential cases of infection may have been missed. This may have occurred by follow up either being too early postoperatively and not identifying infection or being too long postoperatively and mild infection self-resolving or patients seeking out treatment elsewhere.[250] Blinding of assessors was not performed by four studies[106,181,183,185] and this introduces bias into the assessment of these findings. The use of standardised definitions of infection at standard time points using blinded assessors will allow for more reliable evidence generation and greater transferability of findings. The Centre for Disease Control and Prevention (CDC) definition of surgical site infection (SSI) requires the presence of infection within 30 days postoperatively[251], so a suggested timeline of postoperative reviews for detecting infection

is review of the patient on day one, then at two weeks and one month postoperatively. This is in keeping with evidence that the majority of postoperative infections in inguinal hernia are detected around two weeks post-procedure.[244,250]

Prophylactic antibiotics were given in seven studies [106,109,181,184,185,187,188], not stated in three studies[180,182,183] and not given in one study.[186] The most recent Cochrane review found that for low risk environments (defined as infection rate < 5%), the benefit of antibiotics on reducing superficial infection could not be confirmed.[120] However, a beneficial effect of antibiotics on superficial infection was found for high risk environments (defined as infection rate > 5%), although the clinical relevance was disputed due to a number needed to treat (NNT) of 29.[12,120] Studies from the same country in this Cochrane review fell into both high and low risk environments, highlighting the institutional variation and multiple contributing factors that affect infection rates.[119,120] A local audit of practice to determine the infection risk should ideally be undertaken in order to guide the use of prophylactic antibiotics in LMICs intending to use low cost mesh in elective primary unilateral inguinal hernioplasty. Sites that determine that they are a high-risk environment should use prophylactic antibiotics, appropriate to cover the common pathogens involved in SSI.[252] The implementation of World Health Organisation (WHO) recommendations to reduce SSI, such as preoperative bathing and use of alcohol-based antiseptic solutions for skin preparation, should be implemented.[253,254]

Two studies provided routine postoperative oral antibiotics for all patients, with Pradhan et al. providing an initial three day course and extended longer courses for those that had evidence of infection[185] and Jain et al. providing a five day course for all patients.[182] There is no evidence for use of routine postoperative antibiotics in reducing SSI but this persists due to operator concern regarding infection.[254,255] The risks of unnecessary antibiotic use are increasing resistance, cost, allergic reactions and Clostridium Difficile infection[254,255], so this should be avoided.

Finally, Darokar et al. included eight patients who underwent emergency surgery, two in the intervention group and six in the control group.[106] Raw patient data was requested from the authors but was not obtained and so all patients were included in the final analysis. There

was no statistically significant difference between the control and intervention groups and a sensitivity analysis without this study included did not change the final outcome. The patients in the Darokar et al. study had incarcerated hernias but none required bowel resection.[106] The literature is supportive of the use of mesh in this clinical situation, but this is often an operating surgeon decision and not routinely performed despite this growing clinical evidence base.[256]

Deep infection was not well defined by the study authors with only Freudenberg et al., Jain et al., Löfgren et al. and Pradhan et al. providing explicit definitions.[109 182 185] All 11 studies reported on deep infection, with just one event in the intervention group.[186] Our meta-analysis showed a relative risk of RR 2.94 (0.12-71.15; very low certainty). This was an extremely imprecise finding and is not clinically meaningful. This imprecision is due to the rarity of deep infection and the low sample size, which did not meet optimal information size.

In keeping with the wider literature, deep infection involving mesh is a rare event, occurring in approximately 1% or less of total cases.[119,120,257] The CDC definition of deep SSI states infection must occur within 12 months postoperatively for hernioplasty[251] and eight studies conducted follow up for at least 12 months.[106,180,186 181,182,184,187,188] The median duration to onset of early mesh infection was noted to be 4 months in one study[258] and 9.6 months in another[259], so this review likely does provide a clinically useful assessment. However, there is a known risk of delayed or late mesh infection with reports of infection up to 4.5 years postoperatively.[118,260,261] The maximum period of follow up was 5 years in the study conducted by Gundre et al., so the likelihood of detection of these rare, late-onset events is small.[181]

As for superficial infection, the use of a standardised definition of deep infection, the use of blinded assessors and review at fixed timepoints of 6 and 12 months postoperatively will facilitate detection of deep infection. The long term infection risk of low cost mesh would require a prospective database to track and record individual patient outcomes over long time frames, similar to those used in orthopaedics and the HerniaMed registry.[262,263] The challenges of maintaining such a database would be best met by an urban or university

affiliated hospital, which could then disseminate information to district and regional hospitals.

Explantation

Explantation is an uncommon complication of hernioplasty and is most commonly related to either deep infection, chronic pain or hernia recurrence.[13,30] Rarer causes of explantation include mesh migration.[12]

Our meta-analysis showed a relative risk of RR 2.93 (0.31-27.71; very low certainty) for explantation using low cost mesh. This was an extremely imprecise finding and is not clinically meaningful. There was little to no evidence of an effect (p = 0.35). The imprecision of this finding is due to the rarity of the event and the insufficient sample size to determine an effect (optimal information size was not reached).

Risk factors associated with mesh infection and eventual explantation include obesity, smoking, diabetes or other medical comorbidities causing immunosuppression[257,259,261], ASA > 3 and emergency operation.[257] The majority of patients in this review underwent elective operations, had ASA < 3 and were excluded if they had immunosuppression. Additionally, three studies reported BMI[186-188] and patients had BMI in the normal or overweight categories. Thus, these studies minimised the risk of infection and subsequently, explantation. Recurrence during hernioplasty is often related to technical errors[8,13] and recurrence is higher in less experienced clinicians.[264,265] As mentioned, in LMICs, operating clinicians may not be qualified surgeons[266] although there is evidence that with training and supervision, early outcomes are in keeping with the broader literature.[267,268] By including only qualified surgeons, the included studies further minimised the risk of recurrence and subsequent mesh explantation. The duration of follow up in most of the included studies was less than the mean time to recurrence of 15-26 months, although this ranged widely.[269,270] The feasibility of picking up the rare complication of explantation is limited in light of the short follow up.

Seroma

Seroma is a relatively frequent complication of hernioplasty with an incidence ranging between 0.5-12.2%[12] and higher in large and inguinoscrotal hernias.[271] The aetiology is not clearly understood but does include formation of a dead space in tissue planes and an inflammatory response to local trauma and implanted foreign material.[271,272] Risk factors include coagulopathy, liver disease and cardiac insufficiency. It is typically detected clinically and usually self-resolves within the 6-8 weeks postoperatively[12] but may require aspiration when causing pain or if persistent.[271] Mesh repairs carry a higher risk of seroma than non-mesh repair[22] and laparoscopic procedures have higher risk than open.[12] Much of the literature is focused on laparoscopic inguinal hernia and incisional hernia repair rather than open inguinal hernia but a systematic review and meta-analysis suggests that mesh type (lightweight vs heavyweight) does not impact on seroma formation.[273] However, an RCT comparing titanium lightweight mesh against heavyweight mesh in laparoscopic repair did find lower rates of seroma in the lightweight mesh group.[274]

Our meta-analysis of seven studies[106,181-184,187,188] showed a relative risk of RR 1.06 (0.53-2.11; moderate certainty) for seroma using low cost mesh. The risk difference ranged from 11 fewer to 25 more cases per 1000. There was little to no evidence of an effect (p = 0.86). This is not a clinically significant finding as the point estimate and range of incidence of seroma (2.6%, 16/621; 1.2-4.8%) falls within the range of estimates for seroma in the literature.

However, seroma was not defined by any of the studies, in keeping with the wider literature[275] and only four studies had blinded assessors.[182,184,187,188] This introduces variability into detection and recording of seroma and is a source of bias. Furthermore, follow up time points for the studies varied. Four studies reviewed patients at the 4-6 week mark[106 181,182,187], two studies reviewed patients at 2 weeks[184,188] and Pathan et al. did not provide information about the timing of review.[183] After the initial review at 2 weeks postoperatively, Löfgren et al. followed up patients at 12 months postoperatively and Wani et al. at 2 months, so cases of seroma that had self-resolved may have been missed.[184]

Complicated and recurrent hernias were excluded by five studies[181,182,184,187,188] and patients with immunocompromise by three studies.[181,182,187] Only Löfgren et al. recorded presence of inguinoscrotal hernia but still recorded a low rate of seroma incidence.[188] However, the authors reported a high incidence of haematoma and did not incise or drain any postoperative swelling, so it is possible that some haematomas may have been misclassified seromas. In addition, the selection of patients, excluding those with ASA > 3, immunocompromise and complicated hernias does reduce the presence of risk factors that contribute to seroma. While recent evidence based on the Herniamed registry found that immunosuppression did not impact on seroma rates in inguinal hernia repairs[276], this selected population may not be representative of the population in LMICs.

Within the limitations outlined, the use of low cost mesh does not appear to affect rates of seroma formation when compared with surgical mesh. Future studies should aim to provide a definition of seroma, utilise blinded assessors and undertake at least one review at 4-6 weeks postoperatively to maximise identification of seroma.

Haematoma

Haematoma is a relatively frequent complication of inguinal hernia repair with an incidence between 6-16% for wound haematoma[11] and 4.5% for scrotal haematoma.[10] Most haematomas are managed non-operatively unless they place the skin under tension or cause significant pain. In this case, aspiration or evacuation may be required. There is no classification system for haematoma severity[12] and it is not defined as an outcome in most studies.[275] This impacts on identification of clinically relevant haematoma formation. Of the studies in this analysis, only Löfgren et al. defined haematoma.[188] Risk factors for haematoma include incarcerated and recurrent hernias, potentially due to increased difficulty and extent of dissection, and previous bleeding, likely an indicator of bleeding diathesis.[277]

Our meta-analysis of 6 studies[106,180,186 182,184,188] showed a relative risk of RR 1.01 (0.69-1.49; moderate certainty) for haematoma using low cost mesh. The risk difference ranged between 26 fewer to 41 higher cases per 1000. There was little to no evidence of an effect ($p = 0.94$). This is not a clinically significant finding as the point estimate and range of

incidence of haematoma in the low cost mesh group (8.2%; 40/486; 5.8-12.5%) falls within the range of estimates for haematoma in the literature.[11]

This incidence of haematoma in this analysis was impacted by the much higher incidence of haematoma in the study conducted by Löfgren et al.[188] A sensitivity analysis excluding this study revealed an incidence overall of 1.68% and relative risk RR of 0.84 (0.25–2.88; p = 0.79). Löfgren et al. commented on this rate of haematoma and suggested it was a consequence of the larger size of hernias repaired, especially inguino-scrotal hernias.[188]

Inguinoscrotal hernias are more common in LMICs due to limited access to care and consequent longer delay between hernia development and repair.[96,278] The increased size of the hernia and the duration of its presence results in a more complex and lengthier operation, with more dissection required, and a greater dead space into which blood can collect postoperatively. Only Löfgren et al. recorded the proportion of inguinoscrotal hernias treated (39%, 117/299)[188] and this was lower than other studies in the literature (>60%)[96,278,279], potentially reflecting the selection criteria of patients with ASA < 3. Similarly, complicated hernias, while not well defined, were excluded by Chauhan et al. and Wani et al. and this may have included inguinoscrotal hernia.[180,184]

Three studies in this analysis[182,184,188] excluded patients with suspected or known coagulopathy. While bleeding disorders are not common, approximately 1% of the population[280], this study population not representative of the general population and this may have impacted on the incidence of haematoma.

Chauhan et al. used the PHS repair as opposed to Lichtenstein repair.[180] PHS has been shown to be provide comparable results with regards to haematoma in two systematic reviews and meta-analyses of RCTs.[48,208] This would not have impacted on the overall analysis.

Five studies had used blinded assessors.[180,182,184,186,188] Five studies had follow up appointments between 1-2 weeks postoperatively [180,182,184,186,188] facilitating adequate identification of haematoma based on a mean time to haematoma identification or

formation of 4.7 days (±3.8).[277] Darokar et al. reviewed patients one month postoperatively and may have missed haematomas that self-resolved.[106]

Within the limitations noted, there was little to no effect of low cost mesh on haematoma formation. Future studies should aim to provide a definition of haematoma, ensure assessors are blinded and that follow up occurs between 1-2 weeks postoperatively to maximise identification of postoperative haematoma.

Recurrence

Recurrence of hernia after repair is the main reason hernioplasty is favoured over herniorraphy.[22] Rates of recurrence are low, approximately 2%, in large database studies[25] and systematic reviews.[22,23] However, there is a large variation within individual studies depending on hernia site, type of repair, duration of follow up and operator experience.[281] Determining the incidence of recurrence and duration to onset of recurrence is complex. Recurrence increases linearly over time[128,282] and may indicate a delay in recurrence with hernioplasty rather than permanent prevention.[282] Data from the Herniamed registry found that 38% of recurrences occurred within the first 5 years postoperatively.[128]

Reoperation rate is often used as a proxy for recurrence with 10-15% of patients requiring reoperation.[12,283] However, this can underestimate recurrence by missing asymptomatic recurrence and those patients who do not want to proceed to repeat operation, or overestimate recurrence by including patients requiring reoperation for other complications.[283] Actual recurrence rate may be twice the rate of reoperation.[284] This may be amplified in LMICs where patients may be lost to follow up.

Early recurrence after hernioplasty occurs within 5 years and is typically related to operative technique, missed hernia or postoperative complications.[128,281,282] Late recurrence may be related to hernia biology, mesh failure or other patient factors.[128,281,282] Our meta-analysis of nine studies[106,180,186 181-184,187,188] including 1248 patients showed a relative risk of RR 1.44 (0.23-9.04; low certainty) for recurrence using low cost mesh. This was an imprecise finding with the optimal information size not met. The risk difference ranged between 1 fewer to 3 more cases per 1000. There was little to no evidence of an effect (p = 0.70). This is not

clinically relevant finding. The non-event relative risk of RR 1.0 (0.99-1.01; p = 0.83) is indicative that there is no effect of low cost mesh on recurrence compared with surgical mesh.

Follow up duration in these studies varied with the shortest duration of follow up being 6 months for Pathan et al. and 5 years for Gundre et al.[181,183] The remaining studies followed patients for between 12-24 months[106,180,186 182,184,187,188] which is sufficient to pick up early recurrence. This duration of follow up is in keeping with the majority of published literature.[127,285] Potential issues with the durability of low cost mesh and its effect on chronic pain development, which impact on recurrence, would not be detected by this duration of follow up.

Family history of inguinal hernia and smoking are also risk factors that have been identified in recurrence.[282] This information was not well recorded with only Löfgren et al. documenting smoking history and no studies recording family history.[188] The proportion of patients who smoked in this study was less than half of the prevalence suggested by epidemiological data.[188,286-289] This may be due to the exclusion of patients with ASA > 3. The potential effect of under-representing patients who smoke is a reduction in recurrence and by not clarifying family history, genetic components to hernia recurrence may be understated.

Chauhan et al. used the PHS repair rather than the Lichtenstein repair used by the remaining studies.[180] However, the findings of a systematic review found no difference in rate of recurrence between these.[48] This should not impact on the findings of this analysis.

Finally, all studies in this analysis used qualified general surgeons as primary operators.[106,180,186 181-184,187,188] This is not the typical situation in LMICs where surgical providers are often not specialist surgeons but medical officers or health workers.[71,266,270] Lack of experience and training does increase this risk of technical error and recurrence.[264]

Overall, there was no effect of low cost mesh vs surgical mesh on hernia recurrence. However, the limited duration of follow up and exclusion of patients with risk factors for

both complications and recurrence and the use of qualified general surgeons reduces the potential risk of recurrence. This does make this finding less generalisable. Future studies would benefit from longer term follow up of patients to better assess recurrence, although this is challenging even in HICs.[126,127]

Patient satisfaction

Patient reported outcomes (PROs) are beginning to be included alongside clinical outcomes such as recurrence and infection in studies of inguinal hernia repair.[290] This reflects the significant number of hernia repairs conducted annually and the burden of chronic pain secondary to hernioplasty.[291] Patient reported outcome measures (PROMs) are questionnaires that consider aspects of treatment best assessed by patients such as quality of life, pain and foreign body sensation.[292] PROMs can be validated or unvalidated and generic or condition-specific.[275,293] Condition-specific PROMs are more appropriate for use where possible as they provide more nuanced and relevant information.[292,293] As pain has already been separately addressed, this analysis focused on PROs other than pain.

Three studies reported on patient satisfaction and a meta-analysis was not conducted.[109,181,188] Two studies used validated PROMs.[109,188] All three studies had blinded patients.[109,181,188]

The OLQI used by Freudenberg et al. was a locally adapted version of the validated SF-36 and assessed patient responses across 14 questions, ranging from pain and local comfort, paraesthesia and foreign body sensation, functioning across different domains of work, leisure and sexual activity and aesthetic satisfaction.[109,197] This was assessed preoperatively and at 30 days postoperatively. The use of mesh on OLQI scores preoperatively to postoperatively demonstrated very strong evidence of an effect for patients in the surgical mesh group ($p = 0.0001$) and strong evidence of an effect for patients in the low cost mesh group ($p = 0.0091$). However, there was no evidence of an effect between the low cost and surgical mesh groups when comparing either preoperative, postoperative or operative outcome OLQI scores.[109]

Löfgren et al. used the European Quality of Life 5 Dimension scale (EuroQoL 5D) and the IPQ

to review patient satisfaction and quality of life preoperatively, at 2 weeks and 12 months.[188,205,294] The self-assessed health status scores improved for both the low cost and surgical mesh groups pre- to post-operatively and there was no difference in absolute scores or change in scores between groups.[188]

Gundre et al. did not provide information beyond a statement that the majority of patients in both groups were satisfied with scar quality (low cost mesh 91.4% vs surgical mesh 94.3%).[181]

The findings of this review indicate that within the limitations of the data, that low cost mesh provides similar outcomes with regards to PROs when compared with surgical mesh using validated PROMs. Scar quality was also similar between groups on assessment with an unvalidated, simple questionnaire. Studies in the future should aim to use a validated, hernia-specific PROM that can be suitably adapted to the culture and language. Of the existing PROMs, the Carolinas Comfort Scale (CCS), the IPQ and the Activities Assessment Scales (AAS) are the most commonly used and partially validated.[290] This will assist in reducing heterogeneity and facilitate comparison across studies.

Surgeon satisfaction

The history of hernioplasty involves the use of mesh of various material[13] and there are many products available on the market for use.[295] While there are a number of important factors influencing mesh choice, such as pore size, mesh weight and strength[12], there remain numerous meshes with similar characteristics. Surgeon choice of mesh is influenced by training, exposure to and availability of mesh and ease of use.[296] Two studies on sterilisation of mosquito net mesh for use in hernioplasty demonstrated that, for some products, sterilisation at 121°C resulted in significant shrinkage, hardening and brittleness such that they were not suitable for implantation.[112,113]

Surgeon satisfaction with low cost mesh was only reported by Freudenberg et al.[109] Both surgical mesh and the low cost alternative were judged “very practical” for use in hernioplasty with no difficulties in handling on a simple 3 point scale.[109] Stephenson and Kingsnorth found that autoclave sterilisation of a low cost polyester mesh resulted in it

being considered difficult to use compared to other meshes and required a period before operating surgeons were able to adapt.[112] The same mesh was used in another study conducted by Clarke et al., who found all surgeons rated the low cost mesh as "easy" or "neither easy nor difficult" to use.[99] Surgeons reported increasing comfortability using this mesh after 2-5 cases.[99]

The low cost mesh alternatives used in this review were LDPE[187], HDPE[181,183], polyethylene[188], polyester[182], nylon[109], co-polymers of polypropylene/polyethylene[184,185] and polypropylene[180,186]. One study did not provide detail beyond stating it was mosquito net mesh.[106] Many of these polymers, barring LDPE and HDPE, have been used in surgical mesh products.[41,297] It would be reasonable to expect that handling of these meshes would be similar and the evidence suggests that surgeons find this to be the case. However, there is a period of adjustment and methods of improving operator comfort with the low cost mesh should be considered. This could include the opportunity to handle the mesh after sterilisation prior to use intraoperatively and to perform the initial 5 operations in uncomplicated low risk cases with adequate operating time provided so as to minimise unfamiliarity. Finally, Clarke et al. suggest that soaking the low cost mesh in sterile fluid prior to implantation, ensuring that it is cut larger than standard size, providing larger overlap at hernial edges and taking larger suture bites when fixing the mesh to tissue may increase ease of use.[99] If future studies were to assess this outcome, blinding of operating surgeon and the use of Likert scales would facilitate more robust analysis across studies.

Durability and strength of mesh

The benefit of using surgical mesh is that it is designed for use in human inguinal hernia repair, undergoes an iterative research and development process and must meet minimum requirements for strength and sterility.[112,298] There is no such requirement for commercial meshes typically used in other contexts. The physicochemical properties of mesh may vary between producers and across different batches from the same producer.[113] The long-term durability in vivo has not been assessed. There is evidence that nylon mosquito net meshes are weaker than the maximum physiological strain, although the tested mesh was chosen due to its lighter weight.[78] The effect of autoclave steam sterilisation at 121°C also impacts

the properties of low cost mesh, with some meshes melting or shrinking and others increasing in strength.[62,99,111,113]

In this review, only Cingi et al. documented testing of the physicochemical properties and durability of mesh prior to use in vivo[186], although five other studies did record details of the mesh characteristics prior to sterilisation.[109,181,183,184,188] Cingi et al. found that polypropylene mesh resterilised via steam autoclave at 121°C had slightly reduced tensile strength along the length of the mesh and slightly increased strength along the width.[186] The mesh was more extensible along the length and slightly less along the width after sterilisation.[186] In keeping with these findings, Ambroziak et al. and Sanders et al. found that the mechanical properties of various mosquito nets also exhibited anisotropy (differing strength depending on mesh orientation).[1,299] They recommended that low cost meshes could be used in hernioplasty based on their physicochemical characteristics and that the mesh should be oriented such that the stronger side is in the direction of maximum physiological stress, that is, transversely.[1,299]

Electron microscopy has demonstrated changes in the surface structure of polypropylene filaments and in vivo function of fibroblasts after resterilisation.[300] Small tears on the filaments increased the surface area of mesh which may increase the foreign body reaction.[300] The alignment of fibroblasts changed on the resterilised mesh.[300] The clinical effects of these are unproven but could result in poor healing or development of chronic pain and infection.

Mitura et al. tested seven mosquito net meshes, three monofilament and four multifilament.[113] They found that the sterilisation at 121°C affected meshes differently. Sterilisation at 121°C did not alter mosquito net fibre diameter, filament weave, net thickness, tensile strength or tear force in any of the meshes. [113] In two multifilament meshes, the post-sterilisation strength of the smallest single fibre diameter was noted to be less than physiological requirements and may not be suitable for implantation. However, there was also noted to be a significant shrinkage in mesh size of > 40% in the monofilament meshes due to reduction of pore size to < 1mm at sterilisation temperature of 121°C.[113] As

pore size reduced, the mesh weight doubled and there was also an increased subjective sensation of net stiffness.[113]

The durability and strength of low cost mesh after sterilisation was not routinely assessed in the RCTs identified in this review but there were a number of other studies that considered its impact.[1,112,113,299,300] Overall, sterilisation in steam autoclave at 121°C had varied effects on low cost meshes, with changes in strength, size and mesh weight. Future studies should aim to provide information about the physicochemical properties of low cost mesh after sterilisation and this will help to relate mesh characteristics to clinical outcomes more directly. The pre- and post-sterilisation weight, pore size, tensile strength and total surface area should all be recorded.

Sterility of mesh

Medical grade mesh is manufactured under tightly controlled conditions and undergoes low temperature gas sterilisation with ethylene oxide (EtO) gas.[63] Commercial production of low cost meshes does not require the same standards of sterilisation as production of medical grade products. EtO gas sterilisation was developed for use with heat and moisture sensitive devices and does not compromise the polymers used in mesh construction.[301] It is a complex, dangerous and time consuming process that requires highly skilled staff.[301,302] Sterilisation in LMICs is most commonly performed through use of steam autoclaves and ethylene oxide is uncommon due to the resources required.[112,299] Sterilisation at 121°C for 15 minutes is a recommended method of achieving satisfactory sterilisation of medical devices and equipment.[299,301,302]

Only Cingi et al. included an assessment of sterility of low cost mesh prior to use.[186] Resterilised polypropylene was cultured in anaerobic and aerobic media and assessed for bacterial growth up to 30 days. All cultures were negative and there was no difference in clinical infection found.[186] This is supported by the findings of equivalent infection rates when using low cost mesh in hernioplasty in the 10 other RCTs in this review[106,109,180-185,187,188] as well as numerous other experimental studies.[81,97,99,110,202,303-307] One study conducted by Udo et al. noted growth of B. Cereus on one batch of sterilised mesh at 1

week post-sterilisation but found no difference in clinical infection rate.[308] They also noted that this organism is a common contaminant in their laboratory.[308]

Chuahan et al. used a low cost version of the PHS but this constructed intraoperatively from flat surgical mesh.[180] These pieces of mesh would have undergone EtO sterilisation at point of manufacture. For the remaining 10 studies that sterilised the low cost mesh on site[106,109,181-188], five studies used steam autoclaves[109,181-183,186,188] and three used EtO gas.[106,181,185] Two studies did not report on sterilisation technique.[184,187] Access to EtO sterilisation is low outside larger hospitals and this does limit the generalisability. However, more relevant is that these studies were undertaken in majority urban teaching hospitals. It is difficult to accurately assess the impact of sterilisation technique and processes and storage of mesh in hospital based on the limited data pertaining to microbiological testing and sterility testing. Organisational and infrastructure challenges are rife in LMICs and these would have a larger impact in rural and remote hospitals, where storage of surgical products raises a greater concern for risk of contamination.[309,310] The use of low cost mesh from a sterility point of view appears to be safe based on clinical data and limited in vitro microbiological testing. Steam autoclaves are safe to use.[301,302] Limiting the duration of time between sterilisation, packaging, storage and use of the low cost mesh would be a simple means of limiting potential contamination. It would be vital to ensure that theatre staff involved in sterilisation are adequately trained to perform this task prior to commencing use of low cost mesh. Finally, for hospitals intending to introduce low cost mesh hernioplasty, dedicated microbiological testing prior to scheduling hernioplasties and maintaining a patient database to audit infection rates would facilitate early identification of problems in either sterilisation processes or other points of potential contamination.

Cost

Cost of surgical mesh is one of the key factors limiting access to hernioplasty in low and middle income countries and is the primary driver for use of low cost alternatives.[87,270] The cost of low cost mesh encompasses purchase price, conduct of mechanical and microbiological testing of the product, teaching and training of staff to sterilise and prepare the low cost mesh, packaging and storage costs, theatre time utilisation and postoperative care.[137] There may also be additional costs associated with maintaining a database of

patients with low cost mesh implants.

In this review, 10 studies reported cost as an outcome but limited information was provided.[106,180,186 109,181-184,187,188] Nine studies reported only the purchase costs of the low cost and surgical mesh[106,180,186 109,181,183,184,187,188] and Jain et al. provided an overall comparison of the total cost of surgery, including cost of mesh and disposable products.[182]

Löfgren et al. did conduct a cost-analysis of their RCT including medicines and materials, staff time and overhead and capital costs.[137] This was published as a separate article, and found that cost of surgery using surgical mesh was 352% higher than using low cost mesh.[137]

The affordability of low cost mesh is the great drawcard for its use. While it is significantly cheaper to purchase and use, there are costs associated with the safe implantation of low cost mesh hernioplasty that do need consideration. These are not well assessed in the literature. While there is not a need for further studies on cost-effectiveness, practitioners implementing low cost mesh hernioplasty should take these into account as part of their departmental budgeting. In particular, time and resources should be allocated for teaching and training of both clinical and non-clinical theatre staff and maintaining a database of patients with implanted low cost mesh.

Limitations of review

This review did have limitations across searching, study selection and analysis. The search was conducted up until December 2019 in any language and across grey literature. However, two studies, Musaev A et al. and Vasil'ev et al. was not able to reviewed in the full-text despite attempts to contact the authors.[192,193] It is possible that some data was missed. The other reviews in published literature searched databases from inception but in this review searching was limited to 20 years prior as operative technique, experience and materials were considered likely to have changed during this period. Ensuring a limited search time frame was considered to be more likely to provide clinically relevant information.

Despite including only RCTs, there was variability in the reporting of outcomes with CONSORT guidelines not routinely adhered to.[159] This is a global phenomenon present in both HICs and LMICs[311] but particularly prevalent in LMICs[312,313] and in surgery.[314,315] While the inclusion of only RCTs does increase the reliability of the findings of this review, the infrequent definition of outcomes and grading of hernias introduces a source of error, limits analysis and generalisability.[275]

For the majority of studies, baseline patient data was provided but at times this was minimal and difficult to interpret. Similarly, patient flow diagrams were infrequently utilised and documentation of loss to follow up was not clear; in most cases, loss to follow was presumed to be minimal based on assessment of other outcomes. Reporting of outcome data was also challenging with standard deviations and 95% confidence intervals not routinely reported. This information was sought from all study authors but was not received.

Overall, the profile of patients in LMICs requiring inguinal hernia repair differs to the selected population included in this review. By excluding patients with recurrent hernias, medical comorbidities and those presenting emergently, a large proportion of patients who require treatment for hernias in LMICs are not represented.[88,104,188] The majority of studies were conducted in India (7/11; 63%) [106,180-185], at hospitals associated with universities (9/11; 82%) [106,109,180-187] and all utilised qualified general surgeons operating electively.[106,109,180-188] One hospital was described as rural[188] with the remaining being urban or regional hospitals.[106,109,180-187] This is not representative of the practice of hernia repair in LMICs, where non-surgeon physicians and non-medical staff may repair hernias in rural settings with limited access to the resources of urban or large regional hospitals.[71,266] Similarly, sterilisation was performed using ethylene oxide, the industry standard, in three studies.[106,181,185] Sterilisation using ETO is not attainable for most LMIC rural or regional hospitals. These study factors may limit the generalisability and applicability of the findings of this review.

Loss to follow up was not well documented by study authors, with five studies not commenting on this directly.[106,180,181,184,186] In these studies, review of other outcome data

was used to infer loss to follow up at the maximum follow up time point. In the remaining six studies, loss to follow up was uncommon with three studies reporting no loss to follow up [183,185,187], Freudenberg et al. recording loss of 2 patients from each group, Löfgren et al. recording 8 patients from the intervention and 5 from the comparator and Jain et al. documenting 16 patients lost in total.[109,182,188] Further information about loss from each group was requested but not obtained from the author.[182] This rate of loss to follow up is low when compared to the literature for LMICs, across surgical[316,317], maternal and child[318,319] and medical trials[320] and likely represents the urban and university hospital preponderance in these studies. However, as loss to follow up most significantly impacts deep infection, chronic pain and recurrence rates which develop over long periods of time, there may be an under-reported effect for these outcomes.

Chauhan et al. compared PHS against an indigenous version of the same product[180]; the remaining studies compared Lichtenstein repair using low cost mesh against surgical mesh. While PHS has similar outcomes to Lichtenstein repair[48], it is not recommended by the HerniaSurge guidelines in the first instance due to its need to enter both anterior and posterior compartments.[12] More relevant to making a direct comparison against low cost mesh alternatives, while a homemade version of the PHS was used, the mesh product was a surgical mesh – flat prolene. This product would have been sterilised as per industry standard and packaged at time of production. A sensitivity analysis conducted excluding this study did not change the result across any outcome.

Darokar et al. included eight patients who underwent emergency hernioplasty.[106] These patients were not evenly distributed across the intervention and control groups, with two patients in the low cost mesh group and six in the surgical mesh group. None of these patients underwent bowel resection but all did present with obstruction. The literature is supportive of use of mesh in hernioplasty in this setting with no increased rates of infection or recurrence, but this is a surgeon dependent choice and not routinely perofrmed.[12,321,322] In the study context, this may have increased the risk of infection in the control arm. However, this was not seen in the outcomes of the study and a sensitivity analysis excluding this study did not change the results of the meta-analyses for infection.

Implications for practice

Despite the limitations outlined, overall, there was little to no effect of low cost mesh compared with surgical mesh on the studied outcomes. This suggests that under care of suitably experienced operating surgeons, patients treated with safely sterilised low cost mesh have no worse outcomes than when treated with surgical mesh.

The polymers used in low cost mesh vary. While many of these, including HDPE, polyester, and polyethylene, have been used in surgical mesh, the potential for manufacturing variability and effect of sterilisation in unknown. As such, mechanical testing should be conducted prior to use of low cost mesh in hernioplasty to ensure that pre- and post-sterilisation, the product retains sufficient strength as to ensure durable repair. This may be best conducted by a better resourced hospital in the area, which can perform testing once off, and once strength is confirmed, smaller regional and rural centres can use this material with greater confidence.

Microbiological testing is less important, given the low overall infection rates identified in this meta-analysis, but hospitals using low cost mesh should have ensure that sterilisation and repackaging are performed meticulously to ensure that risk of contamination of implanted foreign body material. Where possible, ETO sterilisation is the industry standard and should be considered. For the majority of LMIC regional and rural hospitals where this is not achievable, steam sterilisation at 121°C is satisfactory. Where packaging and storing may potentially be compromised, such as in rural or outreach hospitals, risk of contamination of low cost mesh and subsequent infection, should be minimised by sterilisation close to time of implantation or by limiting storage time prior to use. On-site microbiological testing should ideally be conducted prior to low cost mesh hernioplasty being commenced and a database of patients with implanted mesh constructed so that issues with sterility and infection can be identified early.

The use of prophylactic antibiotics in low cost mesh hernioplasty is uncertain. It is not recommended by HerniaSurge guidelines in the context of elective hernioplasty in low infection countries.[12] The majority of studies included in this review did provide prophylactic

antibiotics and two studies did provide routine postoperative antibiotics. Given that operations in rural and regional settings may occur in relatively rudimentary theatres, patients in these settings routinely present with larger inguinoscrotal hernias that increase the risk of seroma and haematoma formation and may not be easily followed up postoperatively, use of antibiotics prophylactically should be decided by the treating clinician, with oversight from the institution. Infection rates from herniorraphy may be available and used to determine whether prophylactic antibiotics are required. Simple measures as outlined by the WHO recommendation of preoperative measures to reduce surgical site infection should be instituted.[253] Routine postoperative antibiotics should not be prescribed.

Recurrence rates are difficult to assess due to being a rare outcome in this review. The causes for recurrence are varied and often related to operative technique or missed hernia, rather than mesh failure. In this context, and indeed, in reducing operative complications, teaching and training of operating physicians in the Lichtenstein technique is vital to reducing recurrence rate and increasing use of the Lichtenstein hernioplasty over herniorrhaphy in LMICs. Organisations such as Operation Hernia, linkages between HIC hospitals and clinicians and LMIC hospitals and short term medical outreach trips have a role to play in this context.[97,98,267,309,323]

Finally, given the findings of this review, that there was no significant difference in outcomes between hernioplasty utilising low cost mesh and surgical mesh, there is a strong argument for provision of at-price or significantly discounted flat surgical mesh for use in LMICs.[88,100] This would be similar in approach to the provision of Highly Active Anti-Retroviral Therapy in Sub-Saharan Africa to control the HIV/AIDS epidemic.[266]

Implications for research

The studies that comprised this review were all RCTs, a significant advance from earlier assessments of the literature. Despite this however, there were a number of issues with how the studies reported their findings, with few reporting as per the CONSORT guidelines.[159]

Overall, studies did not provide enough detail about methods to facilitate confident assessment of risk of bias using the Risk of Bias 2 tool.[194] Particular areas of improvement are: clear definition of outcomes including use of validated scales or scoring systems of clinical outcomes, rather than reliance on clinician judgement; description of randomisation and allocation concealment methods; and blinding of assessors and patients. These would have increased confidence in the rigour of the studies included.

Baseline patient data was often minimally satisfactory. The use of existing hernia classification systems would be beneficial in objectively assessing hernia size and type. For use in LMICs, the modified Kingsnorth classification which accounts for size of inguinoscrotal hernia may be best choice.[96] When reporting results, the use of participant flow diagrams, or in their absence, inclusion of loss to follow up data for each group, separate to narrative description in the discussion or results is important. Outcome data was at times reported without 95% confidence intervals. This information is vital to include and will assist in interpretation of findings.

The studies included had good assessment of short and medium term outcomes but analysis of chronic pain, recurrence and mesh product related complications including explantation requires long-term follow up. Ideally, these rarer complications are best assessed by large registries. The feasibility of establishment of such a registry should be explored, ideally by clinicians based in LMICs, working in collaboration and using existing resources, such as the Herniamed database.[262] Given that the RCTs conducted in this area have been done so by university affiliated hospitals, it may be that registries can be established by these institutes, with the knowledge gained disseminated to rural and regional hospitals.

Cost-analysis of the use of low cost mesh was limited and typically involved direct comparisons of low cost mesh and surgical mesh purchase prices. Low cost mesh is cheaper than use of commercial surgical mesh. However, there remains scope for further rigorous cost evaluations, encompassing purchase cost, cost of staff time, operating theatre usage, sterilisation and packaging of mesh and assessments of speed of return to function. The benefit of these would be exploratory in nature and assist in highlighting areas of

consideration for rural and regional hospitals with limited financial and staff resources intending to implement low cost mesh hernioplasty.

Surgeon and patient satisfaction with use of low cost mesh remain areas that would benefit from further investigation. Data was limited for both of these outcomes. In light of the findings of this review with regards to complications, it may be feasible to simply conduct observational studies regarding these outcomes or collect and assess patient and surgeon satisfaction via registries tracking implantation of low cost mesh.

Summary of Recommendations

Clinical use of low cost mesh

Mesh related

- The minimum information obtained about LCM prior to implantation should include its weight and lightweight products should be used preferentially
- Assess mesh with physical testing pre and post-sterilisation prior to implantation
    - Record pre- and post-sterilisation weight, pore size, tensile strength and total surface area
- Be aware that mesh construction may change without notice, necessitating retesting
- Implant mesh with strongest fibres oriented transversely

Organisational

- Consider budgetary impact of LCM hernioplasty on staff time and training, need for physical and microbiological testing of mesh and ongoing audit and patient registry costs
- Consider use of a database or registry to record patients with implanted LCM in order to track longterm outcomes
- Aim to implement WHO recommendations to reduce SSI
- Aim for judicious use of prophylactic antibiotics based on local rates of infection ascertained through audit
- Cease use of routine postoperative antibiotics
- Consider dedicated microbiological testing when initiating low cost mesh hernioplasty to ensure that sterilisation processes are adequate
- Using steam autoclave sterilisation at 121°C for LCM is safe
- Limit duration of time between sterilisation, packaging, storage and use of LCM

Surgeon / staff

- Improve surgeon comfortability with low cost mesh through:
    - Allowing time for preoperative handling of sterilised mesh
    - Ensuring first 5 cases conducted on uncomplicated surgical patients,
    - Increasing size of implanted mesh, providing extra overlap at hernia edges, and taking larger bites of mesh when fixating

    - Soaking mesh in sterile or antiseptic fluid prior to implantation to improve pliability and handling of mesh
- Facilitate education and training of operating clinicians in surgical technique in order to improve outcomes
- Ensure theatre and technical staff are educated appropriately so that mesh is adequately sterilised and stored safely

Patient related

- Maximise intraoperative and postoperative analgesia with a multi-modal approach in order to reduce acute pain and minimise risk of chronic pain
- Educate patients about immediate postoperative care – showering, keeping wound clean, limiting strenuous exertion immediately postoperatively
- Aim to link patients in for follow up for at least 1 month postoperatively
    - May be conducted in conjunction with community health workers
- Educate patients about long term risk of mesh infection, recurrence and obstruction

Research into use of low cost mesh

Standardised definition of outcomes

- Chronic pain – use HerniaSurge definition of 3 months of pain, limiting daily activities
- Infection – use CDC definitions of superficial (within 30 days) and deep infection (within 12 months)
- Definition of seroma – prospectively defined outcome as per study authors
- Definition of haematoma – prospectively defined outcome as per study authors

Standardised measurement of outcomes with blinded assessors

- Pain
    - Record preoperative pain scores routinely to assess prevalence of pain in LMICs and to generate a baseline to compare against postoperatively
    - Use standardised measurement tools, either generic (VAS) or specific (IPQ)
    - Measure pain scores preoperatively, 1 day and 1 month postoperatively in order to facilitate detection of acute pain
    - Measure pain scores preoperatively, 1 day, 3 months and 12 months postoperatively in order to facilitate detection of chronic pain

- Infection
    - Use a pre-defined or established infection grading system (Southampton Wound Score)
    - Assess wound day 1, 2 weeks and 1 month postoperatively to facilitate detection of superficial infection
    - Assess wound 6 and 12 months postoperatively to facilitate detection of deep infection
- Seroma
    - Assess wound 4-6 weeks postoperatively
- Haematoma
    - Assess wound 1-2 weeks postoperatively
- Patient satisfaction
    - Use validated inguinal/groin pain specific PROMs (IPQ, CCS or AAS)
- Surgeon satisfaction
    - Measure satisfaction on Likert scale
- Mesh related
    - Record pre- and post-sterilisation weight, pore size, tensile strength and total surface area in order to facilitate comparison with surgical mesh and to correlate with clinical outcomes

Future studies

- Consider long-term follow up study at 10 years to identify rare long-term outcome events
    - Establishment of registry / database for LMIC context

Chapter 5: Conclusion

The use of low cost mesh in hernioplasty in LMICs delivers outcomes that are not significantly different to hernioplasty with hernia-specific surgical mesh. This systematic review identified that for the best assessed outcomes of chronic pain, superficial and deep infection rates, seroma and haematoma formation, mesh explantation and hernia recurrence, there was no significant difference in outcomes between surgical and low cost mesh. For immediate postoperative pain, patient and surgeon satisfaction and physicomechanical characteristics of low cost mesh, data was less forthcoming but again, did not find significant differences in outcome when low cost mesh was compared with surgical mesh. Based on this review, the use of low cost mesh in hernioplasty in LMICs can be recommended as a safe alternative, with the caveats of satisfactory sterilisation and adequately trained operating service providers.

References

1. Ambroziak A, Szepietowska K and Lubowiecka I. Mechanical properties of mosquito nets in the context of hernia repair. Comput Methods Biomech Biomed Engin 2016; 19(3): 286-296.
2. Williams N, O'Connell PR and McCaskie A. Bailey & Love's Short Practice of Surgery, 27th Edition: the Collector's edition, 2018.
3. Malangoni M, Rosen, M. Hernias. In: Townsend CM, Beauchamp, R. D., Evers, B. M., Mattox, K. L., ed. Sabiston Textbook of Surgery: The Biological Basis of Modern Surgical Practice, 20th edn. Philadelphia: Elsevier Saunders, 2017; pp. 1092-1119.
4. Mabula JB and Chalya PL. Surgical management of inguinal hernias at Bugando Medical Centre in northwestern Tanzania: our experiences in a resource-limited setting. BMC Res Notes 2012; 5: 585.
5. Bax T, Sheppard BC and Crass RA. Surgical options in the management of groin hernias. Am Fam Physician 1999; 59(1): 143.
6. Komorowski AL, Domínguez Usero D, Martín-Hidalgo Rodil JR and Morán-Rodríguez J. Sliding Inguinal Hernias. Inguinal Hernia, 2014.
7. McClusky DA, III, Mirilas P, Zoras O, Skandalakis PN and Skandalakis JE. Groin Hernia: Anatomical and Surgical History. Arch Surg 2006; 141(10): 1035-1042.
8. Matthews RD NL. Inguinal hernia in the 21st century: An evidence-based review. Curr Probl Surg 2008; 45(4): 261-312.
9. Turaga K, Fitzgibbons RJ, Jr. and Puri V. Inguinal hernias: should we repair? Surg Clin North Am 2008; 88(1): 127-138, ix.
10. Fitzgibbons RJ, Giobbie-Hurder A, Gibbs JO, Dunlop DD, Reda DJ, McCarthy M, et al. Watchful waiting vs repair of inguinal hernia in minimally symptomatic men: a randomized clinical trial. JAMA 2006; 295(3): 285-292.
11. Simons MP, Aufenacker T, Bay-Nielsen M, Bouillot JL, Campanelli G, Conze J, et al. European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. Hernia 2009; 13(4): 343-403.
12. HerniaSurge Group. International guidelines for groin hernia management. Hernia 2018; 22(1): 1-165.
13. Meshes: benefits and risks, New York: Springer, 2004.
14. Chen DC and Morrison J. State of the art: open mesh-based inguinal hernia repair. Hernia 2019; 23(3): 485-492.
15. Miserez M, Peeters E, Aufenacker T, Bouillot JL, Campanelli G, Conze J, et al. Update with level 1 studies of the European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. Hernia 2014; 18(2): 151-163.
16. Van den Heuvel B, Dwars B, Klassen D and Bonjer H. Is surgical repair of an asymptomatic groin hernia appropriate? A review. Hernia 2011; 15(3): 251-259.
17. Chung L, Norrie J and O'Dwyer PJ. Long-term follow-up of patients with a painless inguinal hernia from a randomized clinical trial. Br J Surg 2011; 98(4): 596-599.
18. O'Dwyer PJ, Norrie J, Alani A, Walker A, Duffy F and Horgan P. Observation or operation for patients with an asymptomatic inguinal hernia: a randomized clinical trial. Ann Surg 2006; 244(2): 167.
19. Bennett DH. Principles in Hernia Surgery. In: Kingsnorth AN and LeBlanc KA, eds. Management of Abdominal Hernias, London: Springer London, 2013; pp. 91-101.

20. Turner RC. A general practitioner primer on groin hernias. Aust J Gen Pract 2018; 47(8): 530-533.
21. Lichtenstein IL, Shulman AG, Amid PK and Montllor MM. The tension-free hernioplasty. The American Journal of Surgery 1989; 157(2): 188-193.
22. Lockhart K, Dunn D, Teo S, Ng JY, Dhillon M, Teo E, et al. Mesh versus non-mesh for inguinal and femoral hernia repair. Cochrane Database Syst Rev 2018; (9).
23. EU Hernia Trialists Collaboration. Repair of groin hernia with synthetic mesh: meta-analysis of randomized controlled trials. Ann Surg 2002; 235(3): 322.
24. Amato B, Moja L, Panico S, Persico G, Rispoli C, Rocco N, et al. Shouldice technique versus other open techniques for inguinal hernia repair. Cochrane Database Syst Rev 2012; (4).
25. Bay-Nielsen M, Kehlet H, Strand L, Malmstrom J, Andersen FH, Wara P, et al. Quality assessment of 26,304 herniorrhaphies in Denmark: a prospective nationwide study. Lancet 2001; 358(9288): 1124-1128.
26. Amid PK. Lichtenstein tension-free hernioplasty: Its inception, evolution, and principles. Hernia 2004; 8(1): 1-7.
27. Deeken CR, Abdo MS, Frisella MM and Matthews BD. Physicomechanical Evaluation of Polypropylene, Polyester, and Polytetrafluoroethylene Meshes for Inguinal Hernia Repair. J Am Coll Surg 2011; 212(1): 68-79.
28. Bay-Nielsen M, Perkins FM and Kehlet H. Pain and functional impairment 1 year after inguinal herniorrhaphy: a nationwide questionnaire study. Ann Surg 2001; 233(1): 1.
29. Schmedt CG, Sauerland S and Bittner R. Comparison of endoscopic procedures vs Lichtenstein and other open mesh techniques for inguinal hernia repair - A meta-analysis of randomized controlled trials. Surg Endosc 2005; 19(2): 188-199.
30. Klinge U and Klosterhalfen B. Modified classification of surgical meshes for hernia repair based on the analyses of 1,000 explanted meshes. Hernia 2012; 16(3): 251-258.
31. Jeans S, Williams GL and Stephenson BM. Migration after open mesh plug inguinal hernioplasty: A review of the literature. Am Surg 2007; 73(3): 207-209.
32. Costello CR, Bachman SL, Ramshaw BJ and Grant SA. Materials characterization of explanted polypropylene hernia meshes. J Biomed Mater Res B Appl Biomater 2007; 83B(1): 44-49.
33. Engelsman AF, van der Mei HC, Busscher HJ and Ploeg RJ. Morphological aspects of surgical meshes as a risk factor for bacterial colonization. Br J Surg 2008; 95(8): 1051-1059.
34. Sajid MS, Leaver C, Baig MK and Sains P. Systematic review and meta-analysis of the use of lightweight versus heavyweight mesh in open inguinal hernia repair. Br J Surg 2012; 99(1): 29-37.
35. Zhu LM, Schuster P and Klinge U. Mesh implants: An overview of crucial mesh parameters. World J Gastrointest Surg 2015; 7(10): 226-236.
36. Robinson TN, Clarke JH, Schoen J and Walsh MD. Major mesh-related complications following hernia repair - Events reported to the Food and Drug Administration. Surg Endosc 2005; 19(12): 1556-1560.
37. Klosterhalfen B, Junge K and Klinge U. The lightweight and large porous mesh concept for hernia repair. Expert Rev Med Devices 2005; 2(1): 103-117.
38. Light D, de Beaux A and Horgan L. Is hernia mesh really that unsafe? Bulletin 2019; 101(3): 88-91.
39. Öberg S, Andresen K and Rosenberg J. Absorbable meshes in inguinal hernia surgery: a systematic review and meta-analysis. Surg Innov 2017; 24(3): 289-298.

40. Bilsel Y and Abci I. The search for ideal hernia repair; mesh materials and types. Int J Surg 2012; 10(6): 317-321.
41. Kalaba S, Gerhard E, Winder JS, Pauli EM, Haluck RS and Yang J. Design strategies and applications of biomaterials and devices for hernia repair. Bioactive materials 2016; 1(1): 2-17.
42. Klosterhalfen B, Klinge U, Schumpelick V and Tietze L. Polymers in hernia repair - common polyester vs. polypropylene surgical meshes. J Mater Sci 2000; 35(19): 4769-4776.
43. McKeen LW. Plastics used in medical devices. Handbook of polymer applications in medicine and medical devices, Elsevier, 2014; pp. 21-53.
44. Rai A, Datarkar A, Arora A and Adwani D. Utility of high density porous polyethylene implants in maxillofacial surgery. J Maxillofac Oral Surg 2014; 13(1): 42-46.
45. Lester H. History and physical chemistry of HDPE. Plastics Pipe Institute, 2010.
46. Li J, Ji Z and Cheng T. Comparison of open preperitoneal and Lichtenstein repair for inguinal hernia repair: a meta-analysis of randomized controlled trials. Am J Surg 2012; 204(5): 769-778.
47. Zhao G, Gao P, Ma B, Tian J and Yang K. Open mesh techniques for inguinal hernia repair: a meta-analysis of randomized controlled trials. Ann Surg 2009; 250(1): 35-42.
48. Sanjay P, Watt DG, Ogston SA, Alijani A and Windsor JA. Meta-analysis of Prolene Hernia System mesh versus Lichtenstein mesh in open inguinal hernia repair. Surgeon 2012; 10(5): 283-289.
49. Pandanaboyana S, Mittapalli D, Rao A, Prasad R and Ahmad N. Meta-analysis of self-gripping mesh (Progrip) versus sutured mesh in open inguinal hernia repair. Surgeon 2014; 12(2): 87-93.
50. Engelsman AF, van Dam GM, van der Mei HC, Busscher HJ and Ploeg RJ. In vivo evaluation of bacterial infection involving morphologically different surgical meshes. Ann Surg 2010; 251(1): 133-137.
51. Sanders D, Lambie J, Bond P, Moate R and Steer JA. An in vitro study assessing the effect of mesh morphology and suture fixation on bacterial adherence. Hernia 2013; 17(6): 779-789.
52. Amid P. Classification of biomaterials and their related complications in abdominal wall hernia surgery. Hernia 1997; 1(1): 15-21.
53. Weyhe D, Cobb W, Lecuivre J, Alves A, Ladet S, Lomanto D, et al. Large pore size and controlled mesh elongation are relevant predictors for mesh integration quality and low shrinkage - Systematic analysis of key parameters of meshes in a novel minipig hernia model. Int J Surg 2015; 22: 46-53.
54. Bringman S, Conze J, Cuccurullo D, Deprest J, Junge K, Klosterhalfen B, et al. Hernia repair: the search for ideal meshes. Hernia 2010; 14(1): 81-87.
55. Hollinsky C, Sandberg S, Koch T and Seidler S. Biomechanical properties of lightweight versus heavyweight meshes for laparoscopic inguinal hernia repair and their impact on recurrence rates. Surgical Endosc 2008; 22(12): 2679-2685.
56. Śmietański M, Śmietańska IA, Modrzejewski A, Simons MP and Aufenacker TJ. Systematic review and meta-analysis on heavy and lightweight polypropylene mesh in Lichtenstein inguinal hernioplasty. Hernia 2012; 16(5): 519-528.
57. Uzzaman MM, Ratnasingham K and Ashraf N. Meta-analysis of randomized controlled trials comparing lightweight and heavyweight mesh for Lichtenstein inguinal hernia repair. Hernia 2012; 16(5): 505-518.

58. Bury K and Śmietański M. Five-year results of a randomized clinical trial comparing a polypropylene mesh with a poliglecaprone and polypropylene composite mesh for inguinal hernioplasty. Hernia 2012; 16(5): 549-553.
59. Nikkolo C, Vaasna T, Murruste M, Seepter H, Kirsimägi Ü and Lepner U. Randomized clinical study evaluating the impact of mesh pore size on chronic pain after Lichtenstein hernioplasty. J Surg Res 2014; 191(2): 311-317.
60. Deeken CR, Abdo MS, Frisella MM and Matthews BD. Physicomechanical evaluation of polypropylene, polyester, and polytetrafluoroethylene meshes for inguinal hernia repair. J Am Coll Surg 2011; 212(1): 68-79.
61. Klinge U, Klosterhalfen B., Müller M., Schumpelik V.,. Foreign Body Reaction to Meshes Used for the Repair of Abdominal Wall Hernias. Eur J Surg 1999; 165(7): 665-673.
62. Peterson HL, Peterson EL, Bouwman RA, Sinniah K, Steffes BC and Fader J. Spectroscopic analysis of metal contents in mosquito nets used in hernia repair surgery. East Cent Afr J Surg 2019; 24(1): 10.
63. Baylón K, Rodríguez-Camarillo P, Elías-Zúñiga A, Díaz-Elizondo J, Gilkerson R and Lozano K. Past, Present and Future of Surgical Meshes: A Review. Membranes 2017; 7(3): 47.
64. Witherspoon P, Bryson G, Wright DM, Reid R and O'Dwyer PJ. Carcinogenic potential of commonly used hernia repair prostheses in an experimental model. Br J Surg 2004; 91(3): 368-372.
65. Zollinger Jr RM. An updated traditional classification of inguinal hernias. Hernia 2004; 8(4): 318-322.
66. Miserez M, Alexandre JH, Campanelli G, Corcione F, Cuccurullo D, Pascual MH, et al. The European hernia society groin hernia classification: simple and easy to remember. Hernia 2007; 11(2): 113-116.
67. Kingsnorth A and LeBlanc K. Hernias: inguinal and incisional. Lancet 2003; 362(9395): 1561-1571.
68. Burcharth J, Pedersen M, Bisgaard T, Pedersen C and Rosenberg J. Nationwide Prevalence of Groin Hernia Repair. PLoS One 2013; 8(1).
69. Primatesta P and Goldacre MJ. Inguinal hernia repair: incidence of elective and emergency surgery, readmission and mortality. Int J Epidemiol 1996; 25(4): 835-839.
70. Shillcutt SD. Cost-effectiveness of Groin Hernia Surgery in the Western Region of Ghana. Arch Surg 2010; 145(10): 954.
71. Ologunde R, Maruthappu M, Shanmugarajah K and Shalhoub J. Surgical care in low and middle-income countries: Burden and barriers. Int J Surg 2014; 12(8): 858-863.
72. Estridge P, Sanders DL and Kingsnorth AN. Worldwide hernia repair: variations in the treatment of primary unilateral inguinal hernias in adults in the United Kingdom and in low- and middle-income countries. Hernia 2019; 23(3): 503-507.
73. AlMarzooqi R, Tish S, Huang LC, Prabhu A and Rosen M. Review of inguinal hernia repair techniques within the Americas Hernia Society Quality Collaborative. Hernia 2019; 23(3): 429-438.
74. Atila K, Guler S, Inal A, Sokmen S, Karademir S and Bora S. Prosthetic repair of acutely incarcerated groin hernias: a prospective clinical observational cohort study. Langenbecks Arch Surg 2010; 395(5): 563-568.
75. Bessa SS, Abdel-fattah MR, Al-Sayes IA and Korayem IT. Results of prosthetic mesh repair in the emergency management of the acutely incarcerated and/or strangulated groin hernias: a 10-year study. Hernia 2015; 19(6): 909-914.

76. Sawayama H, Kanemitsu K, Okuma T, Inoue K, Yamamoto K and Baba H. Safety of polypropylene mesh for incarcerated groin and obturator hernias: a retrospective study of 110 patients. Hernia 2014; 18(3): 399-406.
77. Ohene-Yeboah M and Abantanga FA. Inguinal hernia disease in Africa: A common but neglected surgical condition. West Afr J Med 2011; 30(2): 77-83.
78. Wilhelm TJ, Freudenberg S, Jonas E, Grobholz R, Post S and Kyamanywa P. Sterilized Mosquito Net versus Commercial Mesh for Hernia Repair. Eur Surg Res 2007; 39(5): 312-317.
79. Tabiri S, Owusu E, Abantanga EA, Moten A, Nepogodiev D, Omar O, et al. Mesh versus suture repair of primary inguinal hernia in Ghana. BJS Open 2019; 3(5): 629-633.
80. Beard JH, Ohene-Yeboah M, Tabiri S, Amoako JKA, Abantanga FA, Sims CA, et al. Outcomes After Inguinal Hernia Repair With Mesh Performed by Medical Doctors and Surgeons in Ghana. JAMA Surg 2019; 154(9): 853-859.
81. Kiss A, Corona D and Kiss O. The Use of Mosquito-Net Cloths as Prosthesis in Inguinal Hernia Repair: An Experience in Southern Sudan. Surgical Science 2012; 03(03): 155-157.
82. Waweru J, Barasa M, Mwenda AS and Mwago J. Hernia surgery in Nyeri Provincial General Hospital, Kenya: Our 6 year experience. Annals of African Surgery 2014; 11(2): 3-5.
83. Majholm B, Engbaek J, Bartholdy J, Oerding H, Ahlburg P, Ulrik A-MG, et al. Is day surgery safe? A Danish multicentre study of morbidity after 57,709 day surgery procedures. Acta Anaesthesiol Scand 2012; 56(3): 323-331.
84. Ramyil V, Iya D, Ogbonna B and Dakum N. Safety of daycare hernia repair in Jos, Nigeria. East Afr Med J 2000; 77(6).
85. Stephenson BM and Kingsnorth AN. Inguinal hernioplasty using mosquito net mesh in low income countries: an alternative and cost effective prosthesis. BMJ 2011; 343(dec15 1): d7448-d7448.
86. Ahmad MH, Pathak S and Clement KD. Meta-analysis of the use of sterilized mosquito net mesh for inguinal hernia repair in less economically developed countries. BJS Open 2019; 3(4): 429-429.
87. Yang J, Papandria D, Rhee D, Perry H and Abdullah F. Low-cost mesh for inguinal hernia repair in resource-limited settings. Hernia 2011; 15(5): 485-489.
88. Kingsnorth AN, Clarke MG and Shillcutt SD. Public Health and Policy Issues of Hernia Surgery in Africa. World J Surg 2009; 33(6): 1188-1193.
89. Abantanga F, Hesse A, Sory E, Osen H, Choo S and Abdullah F. Policies for improving access to and quality of essential basic surgical care at district hospitals in Ghana. Post Grad Med J Ghana 2012; 1(1): 3-8.
90. Bagguley D, Fordyce A, Guterres J, Soares A, Valadares E, Guest GD, et al. Access delays to essential surgical care using the Three Delays Framework and Bellwether procedures at Timor Leste's national referral hospital. BMJ open 2019; 9(8): e029812.
91. Barnes-Josiah D, Myntti C and Augustin A. The "three delays" as a framework for examining maternal mortality in Haiti. Soc Sci Med 1998; 46(8): 981-993.
92. Chendjou WT, Christie SA, Carvalho M, Nana T, Wepngong E, Dickson D, et al. The Prevalence and Characteristics of Untreated Hernias in Southwest Cameroon. J Surg Res 2019; 244: 181-188.
93. Nordberg EM. Incidence and estimated need of caesarean section, inguinal hernia repair, and operation for strangulated hernia in rural Africa. Br Med J (Clin Res Ed) 1984; 289(6437): 92-93.

94. Beard JH, Oresanya LB, Ohene-Yeboah M, Dicker RA and Harris HW. Characterizing the Global Burden of Surgical Disease: A Method to Estimate Inguinal Hernia Epidemiology in Ghana. World J Surg 2013; 37(3): 498-503.
95. Warwick A, Oppong C, Boateng DB and Kingsnorth A. Inguinal hernia repair is safe in Africa. East Cent Afr J Surg 2013; 18(2): 14-17.
96. Sanders DL, Porter CS, Mitchell KC and Kingsnorth AN. A prospective cohort study comparing the African and European hernia. Hernia 2008; 12(5): 527-529.
97. Kingsnorth AN, Oppong C, Akoh J, Stephenson B and Simmermacher R. Operation Hernia to Ghana. Hernia 2006; 10(5): 376-379.
98. Contini S. Surgery in developing Countries: why and how to meet surgical needs worldwide. Acta Biomed 2007; 78(1): 4-5.
99. Clarke MG, Oppong C, Simmermacher R, Park K, Kurzer M, Vanotoo L, et al. The use of sterilised polyester mosquito net mesh for inguinal hernia repair in Ghana. Hernia 2009; 13(2): 155-159.
100. Forrester JD, Forrester JA and Yang GP. Surgical Mesh Should Be Made Affordable to Low- and Middle-Income Countries. JAMA Surgery 2016; 151(6): 499-500.
101. Shrime MG, Dare AJ, Alkire BC, O'Neill K and Meara JG. Catastrophic expenditure to pay for surgery worldwide: a modelling study. The Lancet Global Health 2015; 3: S38-S44.
102. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. The Lancet 2015; 386(9993): 569-624.
103. Ohene-Yeboah M, Abantanga F, Oppong J, Togbe B, Nimako B, Amoah M, et al. Some aspects of the epidemiology of external Hernias in Kumasi, Ghana. Hernia 2009; 13(5): 529-532.
104. Ohene-Yeboah M. Challenges of Inguinal Hernia Surgery in Ghana. Postgraduate Med J Ghana 2016; 5(1): 15-19.
105. Ohene-Yeboah M, Beard JH, Frimpong-Twumasi B, Koranteng A and Mensah S. Prevalence of inguinal hernia in adult men in the Ashanti Region of Ghana. World J Surg 2016; 40(4): 806-812.
106. Darokar A, Bele K, Mulmule R and Qazi R. Study of open inguinal hernia repair by mosquito net mesh versus polypropylene mesh. Int J Res Med Sci 2016: 126-130.
107. Sorensen CG and Rosenberg J. The use of sterilized mosquito nets for hernioplasty: a systematic review. Hernia 2012; 16(6): 621-625.
108. Chao TE, Sharma K, Mandigo M, Hagander L, Resch SC, Weiser TG, et al. Cost-effectiveness of surgery and its policy implications for global health: a systematic review and analysis. The Lancet Global Health 2014; 2(6): e334-e345.
109. Freudenberg S, Sano D, Ouangré E, Weiss C and Wilhelm TJ. Commercial Mesh versus Nylon Mosquito Net for Hernia Repair. A Randomized Double-blind Study in Burkina Faso. World J Surg 2006; 30(10): 1784-1789.
110. Yenli EMT, Abanga J, Tabiri S, Kpangkpari S, Tigwii A, Amesiya R, et al. Our Experience with the Use of Low Cost Mesh in Tension-Free Inguinal Hernioplasty in Northern Ghana. Ghana Med J 2017; 51(2): 78-82.
111. Kingsnorth AN, Tongaonkar RR and Awojobi OA. Commentary on: low-cost mesh for inguinal hernia repair in resource-limited settings. Hernia 2011; 15(5): 491-494.
112. Stephenson BM and Kingsnorth AN. Safety and Sterilization of Mosquito Net Mesh for Humanitarian Inguinal Hernioplasty. World J Surg 2011; 35(9): 1957-1960.

113. Mitura K and Koziel S. The influence of different sterilization types on mosquito net mesh characteristics in groin hernia repair. Hernia 2018; 22(3): 483-490.
114. Enyinnah M, Dienye PO and Njoku P. Inguinal mesh hernioplasties: a rural private clinic experience in South Eastern Nigeria. Glob J Health Sci 2013; 5(4): 176-181.
115. Gil J, Rodriguez JM, Hernandez Q, Gil E, Balsalobre MD, Gonzalez M, et al. Do Hernia Operations in African International Cooperation Programmes Provide Good Quality? World J Surg 2012; 36(12): 2795-2801.
116. Gram-Hanssen A, Tolstrup A, Zetner D and Rosenberg J. Patient-Reported Outcome Measures for Patients Undergoing Inguinal Hernia Repair. Front Surg 2020; 7: 17.
117. Sanchez-Manuel FJ, Lozano-Garcia J and Seco-Gil JL. Antibiotic prophylaxis for hernia repair. Cochrane Database Syst Rev 2012; (2).
118. Taylor SG and O'Dwyer PJ. Chronic groin sepsis following tension-free inguinal hernioplasty. Br J Surg 1999; 86(4): 562-565.
119. Cai LZ, Foster D, Kethman WC, Weiser TG and Forrester JD. Surgical Site Infections after Inguinal Hernia Repairs Performed in Low and Middle Human Development Index Countries: A Systematic Review. Surg Infect (Larchmt) 2018; 19(1): 11-20.
120. Orelio CC, Hessen C, Sanchez-Manuel FJ, Aufenacker TJ and Scholten R. Antibiotic prophylaxis for prevention of postoperative wound infection in adults undergoing open elective inguinal or femoral hernia repair. Cochrane Database Syst Rev 2020; (4).
121. Bendavid R and Kux M. Seromas. In: Bendavid R, Abrahamson J, Arregui ME, Flament JB and Phillips EH, eds. Abdominal Wall Hernias: Principles and Management, New York, NY: Springer New York, 2001; pp. 753-756.
122. Nienhuijs SW and Rosman C. Long-term outcome after randomizing prolene hernia system, mesh plug repair and Lichtenstein for inguinal hernia repair. Hernia 2015; 19(1): 77-81.
123. Grant AM. Open mesh versus non-mesh repair of groin hernia: meta-analysis of randomised trials based on individual patient data [corrected]. Hernia 2002; 6(3): 130-136.
124. Kingsnorth A, Britton B and Morris P. Recurrent inguinal hernia after local anaesthetic repair. Br J Surg 1981; 68(4): 273-275.
125. Schumpelick V and Klinge U. Prosthetic implants for hernia repair. Br J Surg 2003; 90(12): 1457-1458.
126. Vos PM, Simons MP, Luitse JSK, van Geldere D, Koelemaij MJW and Obertop H. Follow-up after inguinal hernia repair. Questionnaire compared with physical examination: a prospective study in 299 patients. Eur J Surg 1998; 164(7): 533-536.
127. van Veen RN, Wijsmuller AR, Vrijland WW, Hop WC, Lange JF and Jeekel J. Long-term follow-up of a randomized clinical trial of non-mesh versus mesh repair of primary inguinal hernia. Br J Surg 2007; 94(4): 506-510.
128. Kockerling F, Koch A, Lorenz R, Schug-Pass C, Stechemesser B and Reinpold W. How Long Do We Need to Follow-Up Our Hernia Patients to Find the Real Recurrence Rate? Front Surg 2015; 2: 24.
129. Paajanen H and Varjo R. Ten-year audit of Lichtenstein hernioplasty under local anaesthesia performed by surgical residents. BMC Surg 2010; 10.
130. Arlt GD. Mesh explantation in the groin. Recurrent Hernia: Prevention and Treatment, 2007; pp. 327-332.
131. Kehlet H, Jensen TS and Woolf CJ. Persistent postsurgical pain: risk factors and prevention. Lancet 2006; 367(9522): 1618-1625.

132. Aasvang E and Kehlet H. Classification of chronic pain. Descriptions of chronic pain syndromes and definitions of pain terms. Prepared by the International Association for the Study of Pain, Subcommittee on Taxonomy. Pain Suppl 1986; 3: S1-S226.
133. Aasvang E and Kehlet H. Chronic postoperative pain: the case of inguinal herniorrhaphy. Br J Anaesth 2005; 95(1): 69-76.
134. Alfieri S, Amid PK, Campanelli G, Izard G, Kehlet H, Wijsmuller AR, et al. International guidelines for prevention and management of post-operative chronic pain following inguinal hernia surgery. Hernia 2011; 15(3): 239-249.
135. Nienhuijs SW, Rosman C, Strobbe LJA, Wolff A and Bleichrodt RP. An overview of the features influencing pain after inguinal hernia repair. International Journal of Surgery 2008; 6(4): 351-356.
136. Oppong FC. Innovation in income-poor environments. Br J Surg 2015; 102(2): E102-E107.
137. Löfgren J, Matovu A, Wladis A, Ibingira C, Nordin P, Galiwango E, et al. Cost-effectiveness of groin hernia repair from a randomized clinical trial comparing commercial versus low-cost mesh in a low-income country. Br J Surg 2017; 104(6): 695-703.
138. Patterson T, Currie P, Patterson S, Patterson P, Meek C and McMaster R. A systematic review and meta-analysis of the post-operative adverse effects associated with mosquito net mesh in comparison to commercial hernia mesh for inguinal hernia repair in low income countries. Hernia 2017; 21(3): 397-405.
139. Jordan Z, Lockwood C, Munn Z and Aromataris E. The updated Joanna Briggs Institute Model of Evidence-Based Healthcare. Int J Evid Based Healthc 2019; 17(1):58-71.
140. Zimerman AL. Evidence-based medicine: a short history of a modern medical movement. AMA Journal of Ethics 2013; 15(1): 71-76.
141. Sackett DL, Rosenberg WM, Gray JM, Haynes RB and Richardson WS. Evidence based medicine: what it is and what it isn't. BMJ 1996; 312(7023): 71-72.
142. da Costa BR and Jüni P. Systematic reviews and meta-analyses of randomized trials: principles and pitfalls. Eur Heart J 2014; 35(47): 3336-3345.
143. Bastian H, Glasziou P and Chalmers I. Seventy-Five Trials and Eleven Systematic Reviews a Day: How Will We Ever Keep Up? PLoS Med 2010; 7(9): e1000326.
144. Page MJ, Shamseer L, Altman DG, Tetzlaff J, Sampson M, Tricco AC, et al. Epidemiology and Reporting Characteristics of Systematic Reviews of Biomedical Research: A Cross-Sectional Study. PLoS Med 2016; 13(5): e1002028.
145. Mamdani M, Ching A, Golden B, Melo M and Menzefricke U. Challenges to evidence-based prescribing in clinical practice. Ann Pharmacother 2008; 42(5): 704-707.
146. Leonard E, de Kock I and Bam W. Barriers and facilitators to implementing evidence-based health innovations in low- and middle-income countries: A systematic literature review. Eval Program Plann 2020; 82: 101832.
147. Puchalski Ritchie LM, Khan S, Moore JE, Timmings C, van Lettow M, Vogel JP, et al. Low- and middle-income countries face many common barriers to implementation of maternal health evidence products. J Clin Epidemiol 2016; 76: 229-237.
148. Young JM and Solomon MJ. How to critically appraise an article. Nat Clin Pract Gastroenterol Hepatol 2009; 6(2): 82-91.
149. Tufanaru C, Munn Z, Aromataris E, Campbell J and Hopp L. Chapter 3: Systematic reviews of effectiveness. In: Aromataris E and Munn Z, eds. Joanna Briggs Institute Reviewer's Manual, The Joanna Briggs Institute, 2017.

150. Sadeghi-Bazargani H, Tabrizi JS and Azami-Aghdash S. Barriers to evidence-based medicine: a systematic review. J Eval Clin Pract 2014; 20(6): 793-802.
151. Ehrhardt S and Meyer CG. Transfer of evidence-based medical guidelines to low-and middle-income countries. Trop Med Int Health 2012; 17(2): 144.
152. Edwards A, Zweigenthal V and Olivier J. Evidence map of knowledge translation strategies, outcomes, facilitators and barriers in African health systems. Health Res Policy Syst 2019; 17(1): 16.
153. Aromataris E and Munn Z. Chapter 1: JBI Systematic Reviews. In: Aromataris E and Munn Z, eds. Joanna Briggs Institute Reviewer's Manual, The Joanna Briggs Institute, 2017.
154. Chalmers I and Altman DG. Systematic reviews, BMJ Publishing London, 1995.
155. Aromataris E and Pearson A. The systematic review: an overview. Am J Nurs 2014; 114(3): 53-58.
156. Moher D, Liberati A, Tetzlaff J, Altman DG and The PG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 2009; 6(7): e1000097.
157. Munn Z, Stern C, Aromataris E, Lockwood C and Jordan Z. What kind of systematic review should I conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. BMC Med Res Methodol 2018; 18(1): 1-9.
158. OCEBM Levels of Evidence Working Group. The Oxford 2011 Levels of Evidence. Oxford Centre for Evidence-Based Medicine; 2011.
159. Schulz KF, Altman DG and Moher D. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMJ 2010; 340: c332.
160. Djulbegovic B and Guyatt GH. Progress in evidence-based medicine: a quarter century on. The Lancet 2017; 390(10092): 415-423.
161. Ioannidis JPA. Why Most Published Research Findings Are False. PLoS Med 2005; 2(8): e124.
162. Pearson A, Wiechula R, Court A and Lockwood C. The JBI model of evidence-based healthcare. Int J Evid Based Healthc 2005; 3(8): 207-215.
163. Jordan Z, Lockwood C, Munn Z and Aromataris E. The updated Joanna Briggs Institute model of evidence-based healthcare. Int J Evid Based Healthc 2019; 17(1): 58-71.
164. Pearson A, Weeks S and Stern C. Translation science and the JBI model of evidence-based healthcare, Lippincott Wiliams & Wilkins, 2011.
165. Jordan Z, Lockwood C, Munn Z and Aromataris E. Redeveloping the JBI model of evidence based healthcare. Int J Evid Based Healthc 2018; 16(4): 227-241.
166. Tufanaru C MZ, Aromataris E, Campbell J, Hopp L. Chapter 3: Systematic reviews of effectiveness. In: Aromataris E MZ, ed. JBI Manual for Evidence Synthesis, JBI, 2020.
167. Lefebvre C GJ, Briscoe S, Littlewood A, Marshall C, Metzendorf M-I, Noel-Storr A, Rader T, Shokraneh F, Thomas J, Wieland LS. . Chapter 4: Searching for and selecting studies. In: Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. , ed. Cochrane Handbook for Systematic Reviews of Interventions version 61 (updated September 2020), Cochrane, 2020.
168. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009; 339.
169. McKenzie JE BS, Ryan RE, Thomson HJ, Johnston RV. Chapter 9: Summarizing study characteristics and preparing for synthesis. In: Higgins JPT TJ, Chandler J, Cumpston M, Li T,

Page MJ, Welch VA., ed. Cochrane Handbook for Systematic Reviews of Interventions version 61 (updated September 2020), Cochrane, 2020.
170. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. J Clin Epidemiol 2011; 64(4): 383-394.
171. Vaska AI, Munn Z, Nagra S and Barker TH. Hernioplasty using low cost mesh compared to surgical mesh in low- and middle-income countries: A systematic review protocol. JBI Evid Synth 2020; 18(1): 178-185.
172. Garg AX, Hackam D and Tonelli M. Systematic review and meta-analysis: when one study is just not enough. Clin J Am Soc Nephrol 2008; 3(1): 253-260.
173. Alemayehu C, Mitchell G and Nikles J. Barriers for conducting clinical trials in developing countries-a systematic review. Int J Equity Health 2018; 17(1): 37.
174. Bonsu JM, Frasso R and Curry AE. Lessons from the field: the conduct of randomized controlled trials in Botswana. Trials 2017; 18(1): 503.
175. Yusuf S. Clinical research and trials in developing countries. Stat Med 2002; 21(19): 2859-2867.
176. Zhang D, Freemantle N and Cheng K. Are randomized trials conducted in China or India biased? A comparative empirical analysis. J Clin Epidemiol 2011; 64(1): 90-95.
177. The World Bank. World Bank Country and Lending Groups; [internet]. [cited 2020 6 Nov]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups accessed 6 Nov 2020.
178. Higgins JPT, Sterne JAC, Savović J, Page MJ, Hróbjartsson A, Boutron I, et al. A revised tool for assessing risk of bias in randomized trials. Cochrane Database Syst Rev 2016; (10).
179. Tufanaru C, Munn Z, Stephenson M and Aromataris E. Fixed or random effects meta-analysis? Common methodological issues in systematic reviews of effectiveness. Int J Evid Based Healthc 2015; 13(3): 196-207.
180. Chauhan A, Tiwari S and Gupta A. Study of Efficacy of Bilayer Mesh Device versus Conventional Polypropelene Hernia System in Inguinal Hernia Repair: Early Results. World J Surg 2007; 31(6): 1358-1361.
181. Gundre NP, Iyer SP and Subramaniyan P. Prospective randomized controlled study using polyethylene mesh for inguinal hernia meshplasty as a safe and cost-effective alternative to polypropylene mesh. Updates Surg 2012; 64(1): 37-42.
182. Jain S, Agarwal A, Agarwal L, Meena L, Jain S and Jain M. Randomized trial to compare efficacy of polyester mosquito net mesh with polypropylene mesh in inguinal hernia surgery in northwestern India. Archives of Clinical and Experimental Surgery (ACES) 2016; 5(4).
183. Pathan SS and Kakade SV. Mosquito Net: A Cost Effective Alternative to Prolene Mesh for Inguinal Hernia Repair. New Indian Journal of Surgery 2018; 9(3): 349-353.
184. Wani MM and Durrani AM. Cost effective use of mosquito net mesh in inguinal hernia repair. J Biomed Res 2019; 33(5): 351.
185. Pradhan R and Pangi A. Use of Mosquito Net Mesh Versus Polypropylene Mesh in Tension-Free Repair of Inguinal Hernia: a 1-Year Randomized Controlled Trial. Indian J Surg 2020.
186. Cingi A, Manukyan MN, Güllüoğlu BM, Barlas A, Yeğen C, Yalın R, et al. Use of Resterilized Polypropylene Mesh in Inguinal Hernia Repair: A Prospective, Randomized Study. J Am Coll Surg 2005; 201(6): 834-840.

187. Escobedo E, Esmer-Sánchez D and Hernández-Sierra JF. Utility of a low-density polyethylene mesh in inguinal hernia repair without tension. Invest Clin 2018; 59(4): 318-324.
188. Löfgren J, Nordin P, Ibingira C, Matovu A, Galiwango E and Wladis A. A Randomized Trial of Low-Cost Mesh in Groin Hernia Repair. N Engl J Med 2016; 374(2): 146-153.
189. Mayhew D, Mendonca V and Murthy B. A review of ASA physical status–historical perspectives and modern developments. Anaesthesia 2019; 74(3): 373-379.
190. Ekdahl T, Lofgren J, Wladis A and Nordin P. [Mosquito nets in hernia surgery is an option in low-income countries. Interim analysis of a controlled randomized trial shows positive results]. Lakartidningen 2014; 111(34-35): 1358-1361.
191. Goel S, Agrawal N and Singh N. A Comparative Study of Cost effectiveness of Net Mesh Vs Proline Mesh Inguinal Hernia Repair-An Experience at Rural Area of UP. International Jour nal of Contemporary Surgery 2014; 2(2): 56-58.
192. Vasil'ev S, Moshkova T, Oleĭnik V and Morozov A. Alloplasty of inguinal hernias with polypropylene gauzes. Vestnik khirurgii imeni II Grekova 2007; 166(1): 80-82.
193. Musaev AI and K. ZM. Lichtenstein surgery for the treatment of inguinal hernias. Bulletin of Surgery of Kazakhstan 2013; 2(34).
194. Sterne JA, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019; 366.
195. GRADEpro GDT: GRADEpro Guideline Development Tool [Software]. McMaster University, 2020 (developed by Evidence Prime, Inc.). Available from: gradepro.org.
196. T Distribution Calculator; [internet]. [cited 1 Sep]. Available from: https://stattrek.com/online-calculator/t-distribution.aspx accessed 19 Jun 2020.
197. Ware JE, Jr. and Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992; 30(6): 473-483.
198. Oppong FC. Innovation in income-poor environments: Innovation in income-poor environments. Br J Surg 2015; 102(2): e102-e107.
199. Dubey V. Use of sterilised nylon mosquito net mesh in incisional hernias. Int J Pharma Bio Sci 2014; 5(3): B246-B250.
200. Tongaonkar RR, Reddy BV, Mehta VK, Singh NS and Shivade S. Preliminary Multicentric Trial of Cheap Indigenous Mosquito-Net Cloth for Tension-free Hernia Repair. Indian J Surg 2003; 65(1).
201. Oribabor FO, Amao OA and Akanni SO. The Use of Nontreated Mosquito-Net Mesh Cloth for a Tension Free Inguinal Hernia Repair: Our Experience. Niger J Surg 2015; 21(1): 48-51.
202. Rouet J, Bwelle G, Cauchy F, Masso-Misse P, Gaujoux S and Dousset B. Polyester mosquito net mesh for inguinal hernia repair: A feasible option in resource limited settings in Cameroon? J Visc Surg 2018; 155(2): 111-116.
203. Molegraaf M, Lange J and Wijsmuller A. Uniformity of Chronic Pain Assessment after Inguinal Hernia Repair: A Critical Review of the Literature. Eur Surg Res 2017; 58(1-2): 1-19.
204. Oberg S, Andresen K, Klausen TW and Rosenberg J. Chronic pain after mesh versus nonmesh repair of inguinal hernias: A systematic review and a network meta-analysis of randomized controlled trials. Surgery 2018; 163(5): 1151-1159.
205. Fränneby U, Gunnarsson U, Andersson M, Heuman R, Nordin P, Nyrén O, et al. Validation of an Inguinal Pain Questionnaire for assessment of chronic pain after groin hernia repair. Br J Surg 2008; 95(4): 488-493.

206. Aasvang EK, Gmaehle E, Hansen JB, Gmaehle B, Forman JL, Schwarz J, et al. Predictive Risk Factors for Persistent Postherniotomy Pain. Anesthesiology 2010; 112(4): 957-969.
207. Reinpold W. Risk factors of chronic pain after inguinal hernia repair: a systematic review. Innov Surg Sci 2017; 2(2): 61-68.
208. Decker E, Currie A and Baig MK. Prolene hernia system versus Lichtenstein repair for inguinal hernia: a meta-analysis. Hernia 2019; 23(3): 541-546.
209. Sharma M, Sharma DB, Chandrakar SK and Sharma D. Histopathological Comparison of Mosquito Net with Polypropylene Mesh for Hernia Repair: An Experimental Study in Rats. Indian J Surg 2015; 77(Suppl 2): 511-514.
210. Bakker WJ, Aufenacker TJ, Boschman JS and Burgmans JPJ. Lightweight mesh is recommended in open inguinal (Lichtenstein) hernia repair: A systematic review and meta-analysis. Surgery 2020; 167(3): 581-589.
211. Patel HD, Groen RS, Kamara TB, Samai M, Farahzad MM, Cassidy LD, et al. An estimate of hernia prevalence in Sierra Leone from a nationwide community survey. Hernia 2014; 18(2): 297-303.
212. Hair A, Paterson C, Wright D, Baxter JN and O'Dwyer PJ. What effect does the duration of an inguinal hernia have on patient symptoms? J Am Coll Surg 2001; 193(2): 125-129.
213. Kuubiere C, Alhassan A, Mogre V and Majeed S. The Epidemiology of Hernias in Tamale, Northern Ghana. Adv Res 2015; 3(3): 269-274.
214. Ramji A. Anthropology of Inguinal Hernia. International Journal of Contemporary Medical Research 2019; 6: 30-34.
215. Rao S, Singh P, Gupta D and Narang R. Clinicoepidemiologic profile of inguinal hernia in rural medical college in central India. Journal of Mahatma Gandhi Institute of Medical Sciences 2016; 21(2): 116-121.
216. Rahul BG and Ravindranath GG. Incidence of inguinal hernia and its type in a study in a semiurban area in Andhra Pradesh, India. International Surgery Journal 2016; 3(4): 1946-1949.
217. Balram E. Prevalence of inguinal hernia in Bundelkhand region of India. Ann Int Med Den Res 2016; 2: 137-138.
218. Sulaiman J, Sahayam SJ, Senthurpandian S and Anandan H. A Study of Incidence of Different Types of Groin Hernias in Adults. Int J Sci Study 2018; 5(10): 87-90.
219. Lange JF, Meyer VM, Voropai DA, Keus E, Wijsmuller AR, Ploeg RJ, et al. The role of surgical expertise with regard to chronic postoperative inguinal pain (CPIP) after Lichtenstein correction of inguinal hernia: a systematic review. Hernia 2016; 20(3): 349-356.
220. Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, et al. Surgical training and experience of medical officers in Ghana's district hospitals. Acad Med 2011; 86(4): 529-533.
221. Falk R, Taylor R, Kornelsen J and Virk R. Surgical Task-Sharing to Non-specialist Physicians in Low-Resource Settings Globally: A Systematic Review of the Literature. World J Surg 2020; 44(5): 1368-1386.
222. Bergström S, McPake B, Pereira C and Dovlo D. Workforce Innovations to Expand the Capacity for Surgical Services. In: Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME and Mock CN, eds. Essential Surgery: Disease Control Priorities, Third Edition (Volume 1), Washington (DC): The International Bank for Reconstruction and Development / The World Bank, 2015.
223. Federspiel F, Mukhopadhyay S, Milsom PJ, Scott JW, Riesel JN and Meara JG. Global surgical, obstetric, and anesthetic task shifting: A systematic literature review. Surgery 2018; 164(3): 553-558.

224. Beard JH, Oresanya LB, Akoko L, Mwanga A, Mkony CA and Dicker RA. Surgical Task-Shifting in a Low-Resource Setting: Outcomes After Major Surgery Performed by Nonphysician Clinicians in Tanzania. World J Surg 2014; 38(6): 1398-1404.
225. Schroeder AD, Tubre DJ, Voigt C and Filipi CJ. The State of Surgical Task Sharing for Inguinal Hernia Repair in Limited-Resource Countries. World J Surg 2020; 44(6): 1719-1726.
226. Fregoso G, Wang A, Tseng K and Wang J. Transition from acute to chronic pain: evaluating risk for chronic postsurgical pain. Pain Physician 2019; 22(5): 479-488.
227. Small C and Laycock H. Acute postoperative pain management. Br J Surg 2020; 107(2): e70-e80.
228. Sobol-Kwapinska M, Bąbel P, Plotek W and Stelcer B. Psychological correlates of acute postsurgical pain: A systematic review and meta-analysis. Eur J Pain 2016; 20(10): 1573-1586.
229. Pinto PR, Vieira A, Pereira D and Almeida A. Predictors of Acute Postsurgical Pain After Inguinal Hernioplasty. J Pain 2017; 18(8): 947-955.
230. Rathmell JP, Wu CL, Sinatra RS, Ballantyne JC, Ginsberg B, Gordon DB, et al. Acute post-surgical pain management: a critical appraisal of current practice. Reg Anesth Pain Med 2006; 31(Suppl 1): 1-42.
231. Nordin P, Hernell H, Unosson M and Gunnarsson U. Type of anaesthesia and patient acceptance in groin hernia repair: a multicentre randomised trial. Hernia 2004.
232. Oderda G. Challenges in the management of acute postsurgical pain. Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy 2012; 32(Suppl 9): 6S-11S.
233. Sanjay P and Woodward A. Local versus General Anaesthesia with Prolene Hernia System Mesh for Inguinal Hernia Repair: Early and Long-Term Outcomes. Dig Surg 2008; 25(5): 347-350.
234. Tabiri S, Russell KW, Gyamfi FE, Jalali A, Price RR and Katz MG. Local anesthesia underutilized for inguinal hernia repair in northern Ghana. PLoS One 2018; 13(11).
235. Massaron S, Bona S, Fumagalli U, Battafarano F, Elmore U and Rosati R. Analysis of post-surgical pain after inguinal hernia repair: A prospective study of 1,440 operations. Hernia 2007; 11(6): 517-525.
236. Bugada D, Lavand'homme P, Ambrosoli AL, Klersy C, Braschi A, Fanelli G, et al. Effect of postoperative analgesia on acute and persistent postherniotomy pain: a randomized study. J Clin Anesth 2015; 27(8): 658-664.
237. Nordin P, Zetterström H, Gunnarsson U and Nilsson E. Local, regional, or general anaesthesia in groin hernia repair: multicentre randomised trial. The Lancet 2003; 362(9387): 853-858.
238. Ismaila BO, Alayande BT, Ojo EO and Sule AZ. Inguinal hernia repair in Nigeria: a survey of surgical trainees. Hernia 2019; 23(3): 625-629.
239. Joshi G, Rawal N, Kehlet H and collaboration P. Evidence-based management of postoperative pain in adults undergoing open inguinal hernia surgery. Br J Surg 2012; 99(2): 168-185.
240. Sanjay P and Woodward A. Inguinal hernia repair: local or general anaesthesia? Ann R Coll Surg Engl 2007; 89(5): 497-503.
241. Sanjay P and Woodward A. Local Anaesthetic Inguinal Hernia Repair Performed Under Supervision: Early and Long-Term Outcomes. Ann R Coll Surg Engl 2009; 91(8): 677-680.

242. Ong CK, Seymour RA, Lirk P and Merry AF. Combining paracetamol (acetaminophen) with nonsteroidal antiinflammatory drugs: a qualitative systematic review of analgesic efficacy for acute postoperative pain. Anesth Analg 2010; 110(4): 1170.
243. Engelsman AF, van der Mei HC, Ploeg RJ and Busscher HJ. The phenomenon of infection with abdominal wall reconstruction. Biomaterials 2007; 28(14): 2314-2327.
244. Taylor E, Duffy K, Lee K, Hill R, Noone A, Macintyre I, et al. Surgical site infection after groin hernia repair. Br J Surg 2004; 91(1): 105-111.
245. Gottrup F, Melling A and Hollander DA. An overview of surgical site infections: aetiology, incidence and risk factors. EWMA journal 2005; 5(2): 11-15.
246. Aufenacker TJ, van Geldere D, van Mesdag T, Bossers AN, Dekker B, Scheijde E, et al. The role of antibiotic prophylaxis in prevention of wound infection after lichtenstein open mesh repair of primary inguinal hernia - A multicenter double-blind randomized controlled trial. Ann Surg 2004; 240(6): 955-961.
247. Zamkowski MT, Makarewicz W, Ropel J, Bobowicz M, Kąkol M and Śmietański M. Antibiotic prophylaxis in open inguinal hernia repair: a literature review and summary of current knowledge. Wideochirurgia i inne techniki maloinwazyjne = Videosurgery and other miniinvasive techniques 2016; 11(3): 127-136.
248. Sereysky J, Parsikia A, Stone ME, Castaldi M and McNelis J. Predictive factors for the development of surgical site infection in adults undergoing initial open inguinal hernia repair. Hernia 2020; 24(1): 173-178.
249. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR and The Hospital Infection Control Practices Advisory C. Guideline for Prevention of Surgical Site Infection, 1999. Infect Control Hosp Epidemiol 1999; 20(4): 250-280.
250. Bailey IS, Karran SE, Toyn K, Brough P, Ranaboldo C and Karran SJ. Community surveillance of complications after hernia surgery. BMJ 1992; 304(6825): 469-471.
251. Horan TC, Andrus M and Dudeck MA. CDC/NHSN surveillance definition of health care–associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control 2008; 36(5): 309-332.
252. Korol E, Johnston K, Waser N, Sifakis F, Jafri HS, Lo M, et al. A systematic review of risk factors associated with surgical site infections among surgical patients. PLoS One 2013; 8(12): e83743-e83743.
253. Allegranzi B, Bischoff P, de Jonge S, Kubilay NZ, Zayed B, Gomes SM, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. The Lancet Infectious Diseases 2016; 16(12): e276-e287.
254. Allegranzi B, Zayed B, Bischoff P, Kubilay NZ, de Jonge S, de Vries F, et al. New WHO recommendations on intraoperative and postoperative measures for surgical site infection prevention: an evidence-based global perspective. The Lancet Infectious Diseases 2016; 16(12): e288-e303.
255. Gyedu A, Katz M, Agbedinu K, Donkor P and Mock C. Antibiotics for Groin Hernia Repair According to Evidence-Based Guidelines: Time for Action in Ghana. J Surg Res 2019; 238: 90-95.
256. Hentati H, Dougaz W and Dziri C. Mesh Repair Versus Non-Mesh Repair for Strangulated Inguinal Hernia: Systematic Review with Meta-Analysis. World J Surg 2014; 38(11): 2784-2790.
257. Mavros MN, Athanasiou S, Alexiou VG, Mitsikostas PK, Peppas G and Falagas ME. Risk Factors for Mesh-related Infections After Hernia Repair Surgery: A Meta-analysis of Cohort Studies. World J Surg 2011; 35(11): 2389.

258. Taylor S and O'dwyer P. Chronic groin sepsis following tension-free inguinal hernioplasty. Br J Surg 1999; 86(4): 562-565.
259. Yang H, Xiong Y, Chen J and Shen Y. Study of mesh infection management following inguinal hernioplasty with an analysis of risk factors: a 10-year experience. Hernia 2019.
260. Delikoukos S, Tzovaras G, Liakou P, Mantzos F and Hatzitheofilou C. Late-onset deep mesh infection after inguinal hernia repair. Hernia 2007; 11(1): 15-17.
261. Falagas ME and Kasiakou SK. Mesh-related infections after hernia repair surgery. Clin Microbiol Infect 2005; 11(1): 3-8.
262. Stechemesser B, Jacob DA, Schug-Paß C and Köckerling F. Herniamed: an internet-based registry for outcome research in hernia surgery. Hernia 2012; 16(3): 269-276.
263. de Steiger RN and Graves SE. Orthopaedic registries: the Australian experience. EFORT Open Reviews 2019; 4(6): 409-415.
264. Wilkiemeyer M, Pappas TN, Giobbie-Hurder A, Itani KMF, Jonasson O and Neumayer LA. Does Resident Post Graduate Year Influence the Outcomes of Inguinal Hernia Repair? Ann Surg 2005; 241(6): 879-884.
265. Robson AJ, Wallace CG, Sharma AK, Nixon SJ and Paterson-Brown S. Effects of training and supervision on recurrence rate after inguinal hernia repair. Br J Surg 2004; 91(6): 774-777.
266. Tabiri S, Yenli EMT, Gyamfi FE, Jalali A, Nelson RE, Price RR, et al. The use of mesh for inguinal hernia repair in northern Ghana. J Surg Res 2018; 230: 137-142.
267. Hendra L, Kibaja J, Kibula E and Szymankiewicz M. Muheza approach: a sustainable mesh hernia service in a resource-poor setting and developing a national methodology to hernia surgery in Tanzania. ANZ J Surg 2020.
268. Wang YT, Mehes MM, Naseem HR, Ibrahim M, Butt MA, Ahmed N, et al. Assessing the impact of short-term surgical education on practice: a retrospective study of the introduction of mesh for inguinal hernia repair in sub-Saharan Africa. Hernia 2014; 18(4): 549-556.
269. Klosterhalfen B, Hermanns B, Rosch R and Junge K. Biological Response to Mesh. European Surgery-Acta Chirurgica Austriaca 2003; 35(1): 16-20.
270. Agbakwuru EA, Olasehinde O, Onyeze CI, Etonyeaku AC, Mosanya AO, Wuraola FO, et al. Use of commercial mesh for hernia repair in a low resource setting: experience after 500 cases. Hernia 2019.
271. Li J, Gong W and Liu Q. Intraoperative adjunctive techniques to reduce seroma formation in laparoscopic inguinal hernioplasty: a systematic review. Hernia 2019; 23(4): 723-731.
272. Lau H and Lee F. Seroma following endoscopic extraperitoneal inguinal hernioplasty. Surg Endosc 2003; 17(11): 1773-1777.
273. Currie A, Andrew H, Tonsi A, Hurley PR and Taribagil S. Lightweight versus heavyweight mesh in laparoscopic inguinal hernia repair: a meta-analysis. Surgical Endoscopy and Other Interventional Techniques 2012; 26(8): 2126-2133.
274. Bittner R, Schmedt CG, Leibl BJ and Schwarz J. Early postoperative and one year results of a randomized controlled trial comparing the impact of extralight titanized polypropylene mesh and traditional heavyweight polypropylene mesh on pain and seroma production in laparoscopic hernia repair (TAPP). World J Surg 2011; 35(8): 1791-1797.
275. Bhangu A, Singh P, Pinkney T and Blazeby JM. A detailed analysis of outcome reporting from randomised controlled trials and meta-analyses of inguinal hernia repair. Hernia 2015; 19(1): 65-75.

276. Varga M, Köckerling F, Mayer F, Lechner M, Fortelny R, Bittner R, et al. Are immunosuppressive conditions and preoperative corticosteroid treatment risk factors in inguinal hernia repair? Surg Endosc 2020.
277. Zeb MH, Pandian TK, El Khatib MM, Naik ND, Chandra A, Morris DS, et al. Risk factors for postoperative hematoma after inguinal hernia repair: an update. J Surg Res 2016; 205(1): 33-37.
278. Mabula JB and Chalya PL. Surgical management of inguinal hernias at Bugando Medical Centre in northwestern Tanzania: our experiences in a resource-limited setting. BMC Res Notes 2012; 5(1): 585.
279. Ayoade B. Experience with Lichtenstein Hernioplasty in Sagamu. Annals of Health Research 2015; 1(2): 81-85.
280. Mensah PK and Gooding R. Surgery in patients with inherited bleeding disorders. Anaesthesia 2015; 70(s1): 112-e140.
281. Sarosi GA B-DK. Recurrent inguinal and femoral hernia. In: Ted. W. Post, ed. UpToDate, Waltham, MA: UpToDate, 2020.
282. Junge K, Rosch R, Klinge U, Schwab R, Peiper C, Binnebösel M, et al. Risk factors related to recurrence in inguinal hernia repair: A retrospective analysis. Hernia 2006; 10(4): 309-315.
283. Jenkins JT and O'Dwyer PJ. Inguinal hernias. BMJ 2008; 336(7638): 269-272.
284. Sevonius D, Gunnarsson U, Nordin P, Nilsson E and Sandblom G. Recurrent groin hernia surgery. Br J Surg 2011; 98(10): 1489-1494.
285. Magnusson N, Nordin P, Hedberg M, Gunnarsson U and Sandblom G. The time profile of groin hernia recurrences. Hernia 2010; 14(4): 341-344.
286. Hughes N, Arora M and Grills N. Perceptions and impact of plain packaging of tobacco products in low and middle income countries, middle to upper income countries and low-income settings in high-income countries: a systematic review of the literature. BMJ Open 2016; 6(3).
287. Reitsma MB, Fullman N, Ng M, Salama JS, Abajobir A, Abate KH, et al. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the Global Burden of Disease Study 2015. The Lancet 2017; 389(10082): 1885-1906.
288. Rahal Z, El Nemr S, Sinjab A, Chami H, Tfayli A and Kadara H. Smoking and lung cancer: a geo-regional perspective. Front Oncol 2017; 7: 194.
289. Stone E and Peters M. Young low and middle-income country (LMIC) smokers—implications for global tobacco control. Translational lung cancer research 2017; 6(Suppl 1): S44.
290. Gram-Hanssen A, Jessen M, Christophersen C, Zetner D and Rosenberg J. Trends in the use of patient-reported outcome measures for inguinal hernia repair: a quantitative systematic review. Hernia 2020: 1-10.
291. Gram-Hanssen A, Tolstrup A, Zetner D and Rosenberg J. Patient-reported outcome measures for inguinal hernia repair are insufficiently validated: a systematic review. Int J Qual Health Care 2020; 32(4): 223-230.
292. Gram-Hanssen A, Tolstrup A, Zetner D and Rosenberg J. Patient-Reported Outcome Measures for patients undergoing inguinal hernia repair. Frontiers in Surgery 2020; 7.
293. Zaborszky A, Gyanti R, Barry JA, Saxby BK, Bhattacharya P and Hasan FA. Measurement issues when assessing quality of life outcomes for different types of hernia mesh repair. Ann R Coll Surg Engl 2011; 93(4): 281-285.

294. Rabin R and Charro Fd. EQ-SD: a measure of health status from the EuroQol Group. Ann Med 2001; 33(5): 337-343.
295. Bittner R and Schwarz J. Inguinal hernia repair: current surgical techniques. Langenbecks Arch Surg 2012; 397(2): 271-282.
296. Bilezikian JA, Tenzel PL, Johnson RG, Powers WF and Hope WW. A preliminary evaluation of two different meshes in minimally invasive inguinal hernia surgery. Surg Endosc 2020.
297. Grundfest-Broniatowski S. What would surgeons like from materials scientists?: What would surgeons like from materials scientists? Wiley Interdiscip Rev Nanomed Nanobiotechnol 2013; 5(4): 299-319.
298. Serafini MR, Medeiros Savi F, Ren J, Bas O, O'Rourke N, Maher C, et al. The Patenting and Technological Trends in Hernia Implants (2008-2018). Tissue Eng Part B Rev 2020.
299. Sanders DL, Kingsnorth AN and Stephenson BM. Mosquito Net Mesh for Abdominal Wall Hernioplasty: A Comparison of Material Characteristics with Commercial Prosthetics. World J Surg 2013; 37(4): 737-745.
300. Friedrich M, Meder S, Wedel T, Fischer F, J. Roblick U, Habermann J, et al. Effects of Resterilization on the Surface-Structure of Lightweight Polypropylene Hernia Meshes-An in vitro Study. Res J Med Sci 2010; 4(5): 330-333.
301. Disinfection and Sterilization. Guideline for Disinfection and Sterilization in Healthcare Facilities, Centers for Disease Control and Prevention; 2019.
302. WHO Department of Essential Medicines and Health Products. Methods of sterilization. The International Pharmacopoeia 2019.
303. Darokar A, Bele K, Mulmule R and Qazi R. Open inguinal hernia repair by mosquito net mesh: A five years retrospective study. J Evol Med Dent Sci 2014; 3(40): 10120-10126.
304. Desai G. Economical inguinal hernioplasty for resource poor countries - experience in Zambia. Trop Doct 2007; 37(1): 29-29.
305. Oribabor FO, Amao OA, Akanni SO, Fatudimu SO and Akinola DO. The use of nontreated mosquito-net mesh cloth for a tension free inguinal hernia repair: Our experience. Niger J Surg 2015; 21(1): 48.
306. Tongaonkar RR, Reddy BV, Mehta VK, Singh NS and Shivade S. Preliminary multicentric trial of cheap indigenous mosquito-net cloth for tension-free hernia repair. Indian J Surg 2003; 65(1): 89-95.
307. Tongaonkar RR, Sanders DL and Kingsnorth AN. Ten-Year Personal Experience of Using Low Density Polyethylene (LDPE)Mesh for Inguinal Hernia Repair. Trop Med Surg 2013; 1(5).
308. Udo IA, Onwuezobe IA and Umeh KU. Resterilized Polypropylene Mesh for Inguinal Hernia Repair. Niger J Surg 2018; 24(1): 19-22.
309. Kozieł S, Mitura K, Papaj P and Lorenc Z. Tension-Free Mosquito Net Mesh Inguinal Hernioplasty – an Alternative Exclusively for the Third World? Pol Przegl Chir 2015; 87(2).
310. Forrester JA, Powell L. B., Forrester J. D., Fast C., Weiser T. G. Surgical Instrument Reprocessing in Resource-Constrained Countries: A Scoping Review of Existing Methods, Policies, and Barriers. Surg Infect (Larchmt) 2018; 19(6): 593-602.
311. Chan A-W and Altman DG. Epidemiology and reporting of randomised trials published in PubMed journals. The Lancet 2005; 365(9465): 1159-1162.
312. Diakou LAN, Ntoumi F, Ravaud P and Boutron I. Avoidable waste related to inadequate methods and incomplete reporting of interventions: a systematic review of randomized trials performed in Sub-Saharan Africa. Trials 2017; 18(1): 291.

313. Tharyan P, George AT, Kirubakaran R and Barnabas JP. Reporting of methods was better in the Clinical Trials Registry-India than in Indian journal publications. J Clin Epidemiol 2013; 66(1): 10-22.
314. Adie S, Harris IA, Naylor JM and Mittal R. CONSORT compliance in surgical randomized trials: are we there yet? A systematic review. Ann Surg 2013; 258(6): 872-878.
315. Ali UA, van der Sluis PC, Issa Y, Abou Habaga I, Gooszen HG, Flum DR, et al. Trends in worldwide volume and methodological quality of surgical randomized controlled trials. Ann Surg 2013; 258(2): 199-207.
316. Sandberg CE, Knight SR, Qureshi AU and Pathak S. Using Telemedicine to Diagnose Surgical Site Infections in Low-and Middle-Income Countries: Systematic Review. JMIR mHealth and uHealth 2019; 7(8): e13309.
317. Patterson JT, Albright PD, Jackson JH, Eliezer EN, Haonga BT, Morshed S, et al. Travel barriers, unemployment, and external fixation predict loss to follow-up after surgical management of lower extremity fractures in Dar es Salaam, Tanzania. OTA International 2020; 3(1): e061.
318. Cutland CL, Cunnington M, Olugbosi M, Jones SA, Hugo A, Maharaj K, et al. Lessons learnt from enrolment and follow up of pregnant women and their infants in clinical trials in South Africa, a low-middle income country. Vaccine 2015; 33(47): 6406-6412.
319. T Meloni S, Chaplin B, Chang C, Rawizza H, Okonkwo P and J Kanki P. Patterns of adherence and loss to follow-up in pediatric patients on ART in Nigeria. Current HIV Research 2015; 13(3): 210-218.
320. McMahon JH, Elliott JH, Hong SY, Bertagnolio S and Jordan MR. Effects of physical tracing on estimates of loss to follow-up, mortality and retention in low and middle income country antiretroviral therapy programs: a systematic review. PLoS One 2013; 8(2): e56047.
321. Elsebae MM, Nasr M and Said M. Tension-free repair versus Bassini technique for strangulated inguinal hernia: a controlled randomized study. Int J Surg 2008; 6(4): 302-305.
322. Pandey H, Thakur DS, Somashekar U, Kothari R, Agarwal P and Sharma D. Use of polypropylene mesh in contaminated and dirty strangulated hernias: short-term results. Hernia 2018; 22(6): 1045-1050.
323. Grimes C and Lavy C. Role of UK Hospitals in Supporting Surgical Training in Africa. Bulletin 2010; 92(10): 1-4.

Appendices

Appendix 1: Search strategies

Database

PubMed

PubMed search conducted 09/11/2020

Search (((((("Hernia"[Mesh] OR "Herniorrhaphy"[Mesh] OR "Hernia/surgery"[Mesh])))) OR ((Hernia[Title/Abstract] OR Hernia repair[Title/Abstract] OR Inguinal hernia[Title/Abstract] OR Inguinal hernia repair[Title/Abstract] OR Hernioplasty[Title/Abstract] OR Mesh repair[Title/Abstract] OR Lichtenstein repair[Text Word] OR Groin hernia[Text Word] OR Groin hernia repair[Text Word] OR Tension free repair[Text Word] OR Herniorraphy[Text Word]))))) AND ((((("Surgical Mesh"[Mesh] OR "Mosquito Nets"[Mesh] OR "Culicidae"[Mesh])))) OR ((mesh[Title/Abstract] OR Mosquito net[Title/Abstract] OR Mosquito net mesh[Text Word] OR Low cost[Text Word] OR Low cost mesh[Text Word] OR Hernia implants[Text Word] OR Resterilized mesh[Text Word] OR Sterilized mesh[Text Word] OR resterilised mesh[Text Word] OR sterilised mesh[Text Word] OR Surgical mesh[Text Word] OR Commercial mesh[Text Word] OR Polypropylene[Text Word] OR Polyethylene[Text Word] OR Nylon[Text Word] OR Polyester[Text Word] OR Non-commercial mesh[Text Word] OR Prosthesis[Text Word] OR Low density polyethylene[Text Word])))) Filters: Publication date from 2000/01/01

Embase

Embase search conducted 25/11/2019

(('Hernia'/exp OR 'Herniorrhaphy'/exp OR 'hernioplasty'/exp) OR ('Hernia':ab,ti OR 'Hernia repair':ab,ti OR 'Inguinal hernia':ab,ti OR 'Inguinal hernia repair':ab,ti OR 'Hernioplasty':ab,ti OR 'Mesh repair':ab,ti OR "Lichtenstein repair" OR "Groin hernia" OR "Groin hernia repair" OR "Tension free repair" OR "Herniorraphy")) AND (('Surgical Mesh'/exp OR 'bed nets'/exp OR 'bioabsorbable mesh'/exp OR 'marlex'/exp OR 'polyethylene terephthalate'/exp OR 'nonabsorbable mesh'/exp OR 'polyglactin suture'/exp) OR ('mesh' OR 'Mosquito net' OR "Mosquito net mesh" OR "Low cost" OR "Low cost mesh" OR "Hernia implants" OR "Resterilized mesh" OR "Sterilized mesh" OR "Resterilised mesh" OR "Sterilised mesh" OR "Surgical mesh" OR "Commercial mesh" OR "Polypropylene" OR "Polyethylene" OR "Nylon" OR "Polyester" OR "Non-commercial mesh" OR "Prosthesis" OR "Low density polyethylene")) AND [1999-2019]/py

Scopus

Scopus search conducted 25/11/2019

((KEY ("Hernia") OR KEY ("Herniorrhaphy") OR KEY ("Hernia surgery") OR KEY ("Hernioplasty")) OR (TITLE-ABS-KEY (hernia) OR TITLE-ABS-KEY ("Hernia repair") OR TITLE-ABS-KEY ("Inguinal hernia") OR TITLE-ABS-KEY ("Inguinal hernia repair") OR TITLE-ABS-KEY (hernioplasty) OR TITLE-ABS-KEY ("Mesh repair") OR ALL ("Lichtenstein repair") OR ALL ("Groin hernia") OR ALL ("Groin hernia repair") OR ALL ("Tension free repair") OR ALL (herniorraphy))) AND ((KEY ("Surgical Mesh") OR KEY ("Mosquito Nets") OR KEY (culicidae) OR KEY ("Bed nets") OR KEY ("bioabsorbable mesh") OR KEY ('marlex') OR KEY ("polyethylene terephthalate") OR KEY ("nonabsorbable mesh") OR KEY ("polyglactin suture")) OR (TITLE-ABS-KEY (mesh) OR TITLE-ABS-KEY ("Mosquito net") OR TITLE-ABS-KEY ("Mosquito net mesh") OR ALL ("Low cost") OR ALL ("Low cost mesh") OR ALL ("Hernia implants") OR ALL ("Resterilized mesh") OR ALL ("Sterilized mesh") OR ALL ("Resterilised mesh") OR ALL ("Sterilised mesh") OR ALL ("Surgical mesh") OR ALL ("Commercial mesh") OR ALL ("Polypropylene") OR ALL ("Polyethylene") OR ALL ("Nylon") OR ALL ("Polyester") OR ALL ("Non-commercial mesh") OR ALL ("Prosthesis") OR ALL ("Low density polyethylene"))) PUBYEAR > 1999

Web of Science

Web of Science search conducted 25/11/2019

TS=(Hernia) OR TS=(Herniorrhaphy) OR TS=(Herniorraphy) OR TS=(Hernia surgery) OR TS=(hernioplasty) OR TS=("Hernia repair") OR TS=("Inguinal hernia") OR TS=("Inguinal hernia repair") OR TS=("Mesh repair") OR TS=("Lichtenstein repair") OR TS=("Groin hernia") OR TS=("Groin hernia repair") OR TS=("Tension free repair") OR TS=("Herniorraphy") AND TS=(Surgical Mesh) OR TS=(Mosquito Nets) OR TS=("mesh") OR TS=("Mosquito net") OR TS=("Mosquito net mesh") OR TS=("Low cost") OR TS=("Low cost mesh") OR TS=("Hernia implants") OR TS=("Resterili*ed mesh") OR TS=("Sterili*ed mesh") OR TS=("Surgical mesh") OR TS=("Commercial mesh") OR TS=("Polypropylene") OR TS=("Polyethylene") OR TS=("Nylon") OR TS=("Polyester") OR TS=("Non-commercial mesh") OR TS=("Prosthesis") OR TS=("Low density polyethylene")

Indexes=SCI-EXPANDED, ESCI, CCR-EXPANDED, IC Timespan=2000-2019

Grey literature

Proquest

Proquest search conducted 25/11/2019

Noft(hernia), Date: After 31 December 1999, Source type: Conference Papers & Proceedings, Dissertations & Theses, Working Papers

Web of Science Conference Proceedings

Web of Science Conference Proceedings search conducted 25/11/2019

TS=(Hernia) OR TS=(Herniorrhaphy) OR TS=(Herniorraphy) OR TS=(Hernia surgery) OR TS=(hernioplasty) OR TS=("Hernia repair") OR TS=("Inguinal hernia") OR TS=("Inguinal hernia repair") OR TS=("Mesh repair") OR TS=("Lichtenstein repair") OR TS=("Groin hernia") OR TS=("Groin hernia repair") OR TS=("Tension free repair") OR TS=("Herniorraphy") AND TS=(Surgical Mesh) OR TS=(Mosquito Nets) OR TS=("mesh") OR TS=("Mosquito net") OR TS=("Mosquito net mesh") OR TS=("Low cost") OR TS=("Low cost mesh") OR TS=("Hernia implants") OR TS=("Resterili*ed mesh") OR TS=("Sterili*ed mesh") OR TS=("Surgical mesh") OR TS=("Commercial mesh") OR TS=("Polypropylene") OR TS=("Polyethylene") OR TS=("Nylon") OR TS=("Polyester") OR TS=("Non-commercial mesh") OR TS=("Prosthesis") OR TS=("Low density polyethylene")

Indexes=CPCI-S, Timespan=2000-2019

MedNar

MedNar search conducted 25/11/2019

Full record: (“inguinal” OR “groin”) AND “mesh”

Title: “hernia”

From: 2000

ClinicalTrials.gov

ClinicalTrials.gov search conducted 25/11/2019

Search: inguinal hernia; applied filters interventional, adult, older adult, start date on or after 01/01/2000

WHO International Clinical Trials Registry Platform

WHO ICTRP search conducted 25/11/2019

Search: Ti: hernia AND condition: inguinal OR groin, recruitment status: all, date of registration 01/01/2000

Google Scholar

Google Scholar search conducted 25/11/2019

(randomised OR randomized) AND ("hernia repair" OR hernioplasty OR herniorrhaphy OR "hernia surgery") AND (mesh OR "commercial mesh" OR "low cost" OR sterilised OR sterilized) AND "inguinal hernia" -umbilical -incisional -"non-mesh" -laparoscopic

Limits: date range: 2000 - , include patents

Appendix 2: Data extraction tool

Column1	Columı	Colu	Column4	Column42	Column5	Column52	Column6	Column7	Column74	Column73	Column733	Column732	Column7322	Column7323	Column72	Column722
Study design					Sample size		Group size		Follow up duration (mean±SD, months)		Follow up duration (median, months)		Follow up duration (IQR, months)		Loss to follow up	
Author	**Year**	**RCT**	**Randomization**	**Blinding**	**Patients**	**Hernias**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**
Chauhan	2007	Y	Random number generator	Double blind	84	Not recorded	40	44	13.7±3.0	13±3.6	-	-			0	0
Cingi	2005	Y	Randomisation table	Single blinded	184	184	93	91	-	-	24.3	24.2	16.9	14.9	0	0
Darokar	2015	Y	Random allocation - no further information	Unclear	73	78	37	36	20	-	-	-	-	-	0	0
Escobedo	2018	Y	Random allocation by computer program	Double blind	28	31	16	15	18	18					0	0
Freudenberg	2006	Y	Random allocation - no further information	Double blind	35	40	20	20	1	1					2	2
Gundre	2011	Y	Sealed envelopes	Single blinded	70	Not recorded	35	35	-	-	-	-			0	0
Jain	2016	Y	Random selection from box	Double blind	170	215	107	108	12	12					16 total	
Lofgren	2016	Y	Random sequence generator (computer)	Double blind	302	302	151	151	12	12					8	5
Pathan	2018	Y	Random allocation - no further information	Unclear	200	224	100	100	6	6					0	0
Wani	2019	Y	Random sequence generator (computer)	Double blind	100	106	50	50	19	19					0	0
Pradhan	2020	Y	Randomization, not otherwise specified; hospital based	Unclear	60	69	29	31	Follow up to 10 days	Follow up to 10 days					0	0
					1306	1403	678	681								

Column8	Column82	Column9	Column93	Column92	Column922	Column10	Column11	Column112	Column12	Column122	Column123	Column124	Column13	Column132	Column14	Column143
Demographics	Male:Female		Age range		Age mean (years±SD)		BMI (mean±SD)		ASA I-II		ASA III-IV				Surgical	
Country	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Intervention**	**Comparator**	**Pediatric patients Y/N**	**Paed patient:adult patient**	**Surgeon Yes/No**	**Hospital type**
India	40:0	44:0	-	-	47	44.2	-	-	-	-	-	-	N	N/A	Y	military hospital
Turkey	83:10	82:9	18-89	18-90	55.8	56.9	25.1±3.9	25.4±3.9	93	91	-	-	N	N/A	Y	university hospital
India	37:0	36:0	32-83	19-84	55.6	53.1	-	-	-	-	-	-	N	N/A	Y	university hospital
Mexico	14:2	13:2	-	-	51.6±14.2	49.8±18.1	26.6±11.1	25.8±9.2	16	14	0	1	Y	Not reported	Y	university hospital
Burkina Faso	not reported	not reported	-	-	35.3±14.3	33±11.2			20	20	-	-	Unknown	not reported	Y	university hospital
India	35:0	35:0	18-73	17-70	-	-							Y	1:69	Y	university hospital
India	106:1	107:1	-	-	51.6±16.3	51.7±16.9					-	-	Y	1:169	Y	university hospital
Uganda	151:0	151:0	-	-	45.1±17.6	46.4±17.8	21.5±2.5	20.8±2.2	149	149	1	0	N	N/A	Y	mission hospital
India	100:0	99:1	20-80	20-80	50	50							N	N/A	Y	university hospital
India	not reported	not reported	23-80	23-80	50.4	50.7			50	50	-	-	N	N/A	Y	university hospital
India	29:0	31:0	-	-	45.9±10.3	40.6±14.8	-	-	-	-	-	-	N	N/A	Y	university hospital

Column142	Column15	Column16	Column162	Column17	Column18	Column19	Column20	Column21	Column24	Column25	Column26	Column27
Hernia type Indirect:Direct		Hernia side R:L							Mesh			
Intervention	Comparator	Intervention	Comparator	Hernia classification used	Anaesthetic type (GA/spinal/LA)	Prophylactic abx	Abx choice	Repair type	Mesh used: nylon, polyester, polyethylene, combination, resterilized, indigenous	Sterilization technique	Sterilisation temp (deg C)	Sterilisation time (min)
-	-	-	-	-	4/8/72	Not stated	N/A	PHS	Polypropylene indigenous version of PHS	Sterilised at production		
53:40	41:50	-	-	Nyhus	92/92/0	N	N/A	Lichtenstein	Resterilised polypropylene	Steam autoclave	121	20
-	-	16:18	24:10	-	0/73/0	Y	Amox/clav 1.2g	Lichtenstein	Mosquito net mesh - not defined further	ETO sterilisation		
10:4	10:3	8:8	7:8	-	Not reported	Y	Cephalothin 1g IV or ciprofloxacin 400mg PO	Lichtenstein	LDPE	Not reported		
-	-	16:4	11:9	-	0/40/0	Y	ampicillin 2g	Lichtenstein	Nylon	Steam autoclave		
-	-	-	-		Not reported	Y	ciprofloxacin	Lichtenstein	HPDE	ETO sterilisation		
47:50	38:55	59:48	56:52	-	0/170/0	Not stated	N/A	Lichtenstein	Polyester	Steam autoclave	121	20
					0/0/302	Y	Flucoxacillin 1.5g PO	Lichtenstein	Polyethylene	Steam autoclave	121	20
65:18	69:21				0/200/0	Not stated	Not stated	Lichtenstein	HDPE	Steam autoclave	121	20
38:12	44:6	32:16	28:20		0/100/0	Y	Cefazolin 1g IV	Lichtenstein	Polypropylene/polyethylene co-polymer	Not reported		
-	-	13:9	17:12		0/60/0	Y	Ciprofloxacin 500mg IV	Lichtenstein	Polypropylene/polyethylene co-polymer	ETO sterilisation		

Column28	Column30
General comments	Follow up time points
Study powered for operative time difference; not powered for complications - hence secondary outcomes; included bilateral but not clear how many patients; 12 months duration for follow up	D1, D7, 3monthly
Excluded bilateral inguinal hernia, emergency op, ASA > 2	D1, D7, D14, D21, D28, 6monthly thereafter
Includes 8 patients with emegency surgery; 2 in intervention group, 6 in comparator; also includes bilateral inguinal hernia 3 and 2 intervention and comparator respectively, so hernias 40 in intervention, 38 in comparator; follow up to 30 months max, mean 20	D1, 1, 6, 12 months, annually thereafter
	D7, D30, 3,6,18months
2 patients drop out of each arm due to lack of control follow up (3) and 1 violation of protocol	Preop, D30
Plan for follow up to 60 months, not documented; in discussion, reported as being between 2-5 years	D0 - 12 hours, D1, D7, W6, 3,6,12 month, 3,5 years
Pts given 5 day PO abx course postop	D0 - 6 hours, D1, D8, D15, 1,3,12 months
	W2, 1 year
Includes bilateral hernia, and 3 recurrent herniae; bilateral hernia treated as single entity	6 months total
Planned follow up to 2 years, but appears that follow up until Dec 2012 as per discussion	W2, 2,6, 12 months, 2 years
Planned follow up to 10 days only; southampton infection score used to assess infection; postop ciprofloxacin given 3/7 with longer course in case of infection	D3,5,7,10

Appendix 3: ROB2 Summary / Comments

Study ID	Experimental	Comparator	Outcome	1.1	1.2	Note for 1.1&1.2	1.3	Note for 1.3	1.0 Algorithm result	1.0 Assessor's judgement	1.0 General note	2.1	2.2	Note for 2.1&2.2	2.3	Note for 2.3	2.4	2.5	2.6	Note for 2.6	2.7	2.0 Algorithm result	2.0 Assessor judgement	3.1	Note for 3.1	3.2	3.3	3.4	3.0 Algorithm result	3.0 Assessor judgement	4.1	Note for 4.1	4.2	Note for 4.2	4.3	Note for 4.3	4.4	4.5	4.0 Algorithm result	4.0 Assessor's judgement	4.0 General note	5.1	Note for 5.1	5.2	5.3	5.0 Algorithm result	5.0 Assessor's judgement	Algorithm's overall judgement	Assessor's overall judgement	6.0 General Note
Chauhan	Indigenous bi	PHS	Pain	Y	Y	Patients randomised via independent observer via number generator; unclear about allocation sequence but presumptively yes	NI	Reported as normal, not documented in article - insufficient information to make assessment	Low	Low		PN	PN	Not explicitly stated whether patients blinded, but patient likely informed about use of alternative mesh product during consent; operating surgeon reportedly blinded to allocation but would have been aware of local product being used (have to construt intraoperatively); unlikely that postop team would be aware unless treating surgeon conducting postop rounds, assessor blinded	NA		NA	NA	Y	All patients analysed in group of allocation	NA	Low	Low	Y	No loss to FL	NA	NA	NA	Low	Low	N		N		N	Blinded outcome assessor	NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Chauhan	Indigenous bi	PHS	Operative time	Y	Y		NI		Low	Low		PN	PN		NA		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Chauhan	Indigenous bi	PHS	Haematoma	Y	Y		NI		Low	Low		PN	PN		NA		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Chauhan	Indigenous bi	PHS	Postoperative neuralgia	Y	Y		NI		Low	Low		PN	PN		NA		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Chauhan	Indigenous bi	PHS	Infection	Y	Y		NI		Low	Low		PN	PN		NA		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Chauhan	Indigenous bi	PHS	Recurrence	Y	Y		NI		Low	Low		PN	PN		NA		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised / PP		Operative time	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised / PP		Length of stay	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised / PP		Haematoma	Y	Y	Randomisation table; allocation by nurse unaware until operation scheduled	N	Unclear whether patients blinded, likely informed during consent regarding use of resterilised mesh; assessor blinded, nurse in OT aware of allocation, not clearly stated that surgeon aware	Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised / PP		Infection	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised / PP		Explantation	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised m	PP	Recurrence	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Cingi	Resterilised m	PP	Cost	Y	Y		N		Low	Low		PY	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		PY		N	N	Low	Low	Low	Low			
Darokar	MNM	PP	Haematoma	NI	NI	Stated that study is randomised	N	Patients informed during consent procedure	Some concer	Some concerns		PY	Y		PN	Unlikely that surgical care altered due to context; given postop care protocolised, unlikely that postop op care would have differed either	NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN	Limited information about assessor (?blinded) and how these complications were defined and documented	PY	Given limited information about assessor blinding, lack of definitions of complications, potential for manipulation; however, not applicable for explantation, urinary retention	NA		NA	NA	High	High		NI	Not describe	NI	PN	Some concer	Some concer	High	High	Minimal detail throughout article on details		
Darokar	MNM	PP	Seroma	NI	NI		N		Some concer	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PY		NA		NA	NA	High	High		NI	Not describe	NI	PN	Some concer	Some concer	High	High			
Darokar	MNM	PP	Infection	NI	NI		N		Some concern	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PY		NA		NA	NA	High	High		NI	Not described	NI	PN	Some concern	Some concer	High	High			
Darokar	MNM	PP	Postoperative neuralgia	NI	NI		N		Some concern	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PY		NA		NA	NA	High	High		NI	Not described	NI	PN	Some concern	Some concer	High	High			
Darokar	MNM	PP	Recurrence	NI	NI		N		Some concern	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PY		NA		NA	NA	High	High		NI	Not described	NI	PN	Some concern	Some concer	High	High			
Darokar	MNM	PP	Explantation	NI	NI		N		Some concern	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		NI		PN	NA	Low	Low		NI	Not described	NI	PN	Some concern	Some concer	Some concer	Some concer			
Darokar	MNM	PP	Urinary retention	NI	NI		N		Some concern	Some concerns		PY	Y		PN		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		N		NI		N	NA	Low	Low		NI	Not described	NI	PN	Some concern	Some concer	Some concer	Some concer			
Freudenberg	Nylon	PP	Pain	NI	NI	Minimal information provided	NI	Patients randomised intraoperatively; patients and observer blinded; may be that postop care team aware; operating surgeon aware	Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N	30 day follow up for pain is appropriate; unlikely to pick up mild infections however	N		N		N		NA	NA	Low	Low		PY	Not clearly de	N	N	Low	Low	Some concer	Some concer	Limited information provided on randomisation procedure but otherwise well constructed		
Freudenberg	Nylon	PP	Infection	NI	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	Y	Long period of time between pre and post-op follow up - could miss mild infection	N		N		NA		NA	NA	High	High		PY	Not clearly de	N	N	Low	Low	High	High			
Freudenberg	Nylon	PP	Explantation	NI	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	Y	V short period of time to consider reoperation - only 30 days	N		NA		NA	NA	High	High		PY	Not clearly def	N	N	Low	Low	High	High			
Freudenberg	Nylon	PP	Cost	NI	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		Y	Needs to be aware of cost	N	NA	Low	Low		PY	Not clearly def	N	N	Low	Low	Some concer	Some concern			
Freudenberg	Nylon	PP	Surgeon satisfaction	NI	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PY		Y		NA		NA	NA	High	High		PY	Not clearly def	N	N	Low	Low	High	High			
Gundre	HDPE	PP	Surgeon satisfaction	PY	PY	Randomisation via envelopes; Single blinded	NI	Single blind trial - participants not aware; follow up by operating surgeon	Low	Some concerns	No information on patient groups provided; minimal information about allocation concealment	N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	NI	No information given re: how this outcome was measured	NI		Y		N	NA	Some concer	Some concerns		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation but less relevant for surgeon satisfaction outcome, assesment of satisfaction requires knowledge of material (single blinding not relevant)
Gundre	HDPE	PP	Postoperative neuralgia	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		Y		N	NA	Low	Low		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, POP not easily manipulated by assesor
Gundre	HDPE	PP	Fever	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		Y	PN	Some concer	Some concerns		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, fever open to manipulation by assesor
Gundre	HDPE	PP	Seroma	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		Y	PN	Some concer	Some concerns		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, seroma open to manipulation by assesor (single blind)
Gundre	HDPE	PP	Infection	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		Y	PN	Some concer	Some concerns		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, wound infection assesment can be manipulated by assesor
Gundre	HDPE	PP	Sinus formation	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		Y	PN	Some concer	Some concerns		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, outcome assessment of presence of sinus not easily manipulated by assesor
Gundre	HDPE	PP	Duration to return to functio	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		N	NA	Low	Low		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, outcome assesment for return to function not modifiable by asesor
Gundre	HDPE	PP	Scar quality	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		Y	PN	Low	Low		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, scar quality dependent on assesor
Gundre	HDPE	PP	Explantation	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		N	NA	Low	Low		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation but less relevant for surgeon satisfaction outcome
Gundre	HDPE	PP	Recurrence	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		Y		PY	N	Some concer	Some conce	Single blinded, so assesor could misconstrue recurrance	PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern			Minimal detail on randomisation, single blinded assesor, so open to manipulation for recurrence
Gundre	HDPE	PP	Cost	PY	PY		NI		Low	Some concerns		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		Y		N	NA	Low	Low		PY	Not clear, but i	N	N	Low	Low	Some concer	Some concern	Minimal detail on randomisation, not relevant for cost		
Jain	Polyester	PP	Pain	Y	PY	Simple randomisation via chit box; bilateral herniae used as control/comparator	N	Difficult to conceal which mesh used from care team	Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Seroma	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Urinary retention	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Haematoma	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Infection	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Cost	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			
Jain	Polyester	PP	Recurrence	Y	PY		N		Low	Low		N	PY		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	PN		PN		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low			

Study ID	Experimental	Comparator	Outcome	1.1	1.2	Note for 1.1&1.2	1.3	Note for 1.3	1.0 Algorithm result	1.0 Assessor's judgement	1.0 General note	2.1	2.2	Note for 2.1&2.2	2.3	Note for 2.3	2.4	2.5	2.6	Note for 2.6	2.7	2.0 Algorithm result	2.0 Assessor judgement	3.1	Note for 3.1	3.2	3.3	3.4	3.0 Algorithm result	3.0 Assessor judgement	4.1	Note for 4.1	4.2	Note for 4.2	4.3	Note for 4.3	4.4	4.5	4.6 Algorithm result	4.0 Assessor's judgement	4.0 General note	5.1	Note for 5.1	5.2	5.3	5.0 Algorithm result	5.0 Assessor's judgement	Algorithm's overall judgement	Assessor's overall judgement	6.0 General Note
Lofgren	Polyethylene	PP	Recurrence	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Infection	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Haematoma	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Seroma	Y	Y	Block randomisation, on day of surgery, by computer program;	N		Low	Low		N	Y	Surgeons and nursing staff aware of allocation	N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Impaired wound healing	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Pain	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Urinary retention	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Postoperative neuralgia	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Lofgren	Polyethylene	PP	Mortality	Y	Y		N		Low	Low		N	Y		N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		Y		N	N	Low	Low	Low	Low	
Pathan	HDPE	PP	Cost	NI	NI		NI		Some concer	Some concerns		PY	PY		NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		NI		N	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Limited information throughout study; randomisation method not defined, data not reported consistently, but not relevant to cost
Pathan	HDPE	PP	Seroma	NI	NI		NI		Some concer	Some concerns		PY	PY		NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Some conc	PN		PN	theoretically open to manipulation but unlikely	NI	No information provided on who assessed patients	Y	PN	Some conc	Some concerns		NI		N	N	Some concer	Some concer	Some concer	Some concer	Limited information throughout study; randomisation method not defined, data not reported consistently, unclear if blinded assessor so open to manipulation of seroma
Pathan	HDPE	PP	Infection	NI	NI	Statement that study randomised; no information on patient demographics	NI		Some concer	Some concerns		PY	PY	Consent procedure involved explanation of mesh use	NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Some conc	PN		PN		NI		Y	PN	Some conc	Some concerns		NI		N	N	Low	Low	Some concer	Some concer	Limited information throughout study; randomisation method not defined, data not reported consistently, unclear if blinded assessor so infection open to manipulation
Pathan	HDPE	PP	Impaired wound healing	NI	NI		NI		Some concer	Some concerns		PY	PY		NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Some conc	PN		PN		NI		Y	PN	Some conc	Some concerns		NI		N	N	Low	Low	Some concer	Some concer	Limited information throughout study; randomisation method not defined, data not reported consistently, unclear if blinded assessor so impaired wound healing open to manipulation
Pathan	HDPE	PP	Explantation	NI	NI		NI		Some concer	Some concerns		PY	PY		NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	PN		PN		NI		N	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Limited information throughout study; randomisation method not defined, unclear if blinded assessor, so open to manipulation, but difficult to do so with explantation
Pathan	HDPE	PP	Recurrence	NI	NI		NI		Some concer	Some concerns		PY	PY		NI		NA	NA	Y		NA	Some conc	Some conc	Y	Data reported	NA	NA	NA	Low	Low	PN		PN		NI		Y	PN	Some conc	Some concerns		NI		N	N	Some concer	Some concer	Some concer	Some concer	Limited information throughout study; randomisation method not defined, data not reported consistently, unclear if blinded assessor so open to manipulation of recurrence rates
Wani	Polyethylene	PP	Length of stay	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Seroma	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Haematoma	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Infection	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Orchitis	NI	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Postoperative neuralgia	Y	NI	Used online randomisation tool	NI	Minimal information provided re: baseline charateristics	Some concer	Some concerns		N	PY	Double blind with patients informed about mesh types during consent, but not about which was placed; likely that primary care team aware; patient and observer blinded	N		NA	NA	Y		NA	Low	Low	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Urinary retention	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Duration to return to functi	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Wani	Polyethylene	PP	Recurrence	Y	NI		NI		Some concer	Some concerns		N	PY		N		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N	Short time frame for recurrence; reports last patient enrolled in trial in Dec 2012; follow up until Dec 2012	N		N		NA	NA	Low	Low		NI		N	N	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Recurrence	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Pain	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Explantation	Y	NI	Computer generated random allocation; surgeon being supplied with the corresponding mesh according to the above-mentioned table of random numbers	N		Some concer	Some concerns		N	PY	Likely postop care team aware of mesh type inserted; evaluator and patient blinded	N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Cost	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Postoperative neuralgia	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Infection	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Impaired wound healing	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Seroma	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Escobedo	LDPE	PP	Length of stay	Y	NI		N		Some concer	Some concerns		N	PY		N		NA	NA	NI		N	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		N		N		NA	NA	Low	Low		NI		N	NI	Some concer	Some concer	Some concer	Some concer	Some concerns
Pradhan	Polypropylen	PP	Infection	NI	NI	Hospital based randomised trial	NI		Some concer	Some concerns	Minimal information provided about randomisation, appears unblinded but no information provided; baseline characteristics of patients limited	NI	NI	Blinding not clear	NI		NA	NA	Y		NA	Some conc	Some conc	Y		NA	NA	NA	Low	Low	N		PN	Unclear whether a blinded assessor but using an identified scale - Southampton score	NI		Y	N	Some conc	Some concerns		NI	No information provided on analysis plan	N	N	Some concer	Some concer	Some concer	Some concer	Minimal information provided; looking at single outcome until 10 days postop