



# Mesh migration following abdominal hernia repair: a comprehensive review

H. B. Cunningham<sup>1</sup> · J. J. Weis<sup>2</sup> · L. R. Taveras<sup>1</sup> · S. Huerta<sup>3</sup>

Received: 10 May 2018 / Accepted: 22 January 2019  
© Springer-Verlag France SAS, part of Springer Nature 2019

## Abstract

**Purpose** This study reviewed the literature regarding mesh migration in abdominal hernia repair. The aim of this study is to interrogate incidence, common type of abdominal hernia repair leading to migration, patterns of mesh migration, and materials associated with migration.

**Methods** A comprehensive literature review was conducted. PubMed and MEDLINE were searched for relevant articles in the English literature. We employed Ovid syntax from 1949 to January 2010, the Cochrane Library, Google and Google Scholar. The clinical trial database Clinicaltrials.gov was reviewed. Letters to the editor were reviewed to extract cross-references. Multiple keywords were used alone and in combination to extract all relevant articles.

**Results** In total, 287 unique English citations were reviewed. Of these, 84 articles were selected and consisted of 3 case series, 77 case reports, 2 literature reviews, 1 retrospective study, and 1 prospective, observational study. In an analysis of available cases, the average age was  $59.8 \pm 13.8$  years with a male predominance (76.2%). The index hernia repair was inguinal in 62.9%, incisional/ventral in 28.1%, umbilical in 6.7%, and other in 2.2%. Within the inguinal hernia group, 51.8% were open repairs, 42.9% were laparoscopic, and 1.8% were robotic. Implicated mesh materials included polypropylene, PTFE, and composite mesh. Migration commonly affected multiple organs (31.5%).

**Conclusions** It is likely that more cases of mesh migration will appear in the literature. Reports are heterogeneous and highlight the diversity of this complication. A standardized method of reporting is needed to develop guidelines and recommendations for this presentation.

**Keywords** Mesh migration · Mesh erosion · Hernia repair · Lichtenstein repair · Mesh complications

## Introduction

In 2003, the National Survey of Ambulatory Surgery found that 1.2 million abdominal wall hernias were repaired in the United States for that year alone [1, 2]. The same report

documented that inguinal hernias constituted 66.4% of all abdominal wall hernia repairs with para-umbilical/umbilical and incisional hernia repairs making up an additional 23.8%. Thus, ventral and groin hernia repairs are the most frequent operations performed by general surgeons [3, 4]. Undoubtedly, the use of mesh in hernia repair has been a major landmark in surgical techniques reducing the rate of recurrence significantly [5–10]; however, while associated with a reduction in hernia recurrence rates, other complications of mesh placement are emerging. For instance, surgical site infection [11] and chronic pain [12] following repair of ventral and inguinal hernias have been directly attributed to the increased frequency of mesh utilization.

Mesh migration is an unusual clinical presentation, and its definition has not yet been standardized. One study defined mesh migration as the displacement of a whole mesh into an organ while defining mesh erosion as partial mesh perforation into an organ [13]. Unfortunately, these definitions

---

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s10029-019-01898-9>) contains supplementary material, which is available to authorized users.

---

✉ H. B. Cunningham  
hollybrianne88@gmail.com

<sup>1</sup> University of Texas Southwestern, 5323 Harry Hines Blvd, E5-810, Dallas, TX 75390, USA

<sup>2</sup> University of Texas Southwestern, 5323 Harry Hines Blvd, E7-100, Dallas, TX 75390, USA

<sup>3</sup> VA North Texas Health Care System, 4500 South Lancaster Road, Dallas, TX 75216, USA

have not been universally accepted, and these terms are often used interchangeably. The rarity of this complication may be responsible for significant diagnostic difficulties for physicians and morbidities for patients as well as delays in treatment. Reports of mesh migration after inguinal hernia repair with mesh can be found in the literature as early as 1996 and include involvement of multiple areas of the body such as the bladder [14], small bowel [15], and scrotum [16]. A few authors have conducted literature reviews on the topic of mesh migration, but include very small numbers of cases [17–20]. The paucity of data on mesh migration leads to the current study which aimed to analyze the existing literature with the hypothesis that any type of hernia repair is at risk of this complication. Second, we sought to determine the best clinical practices which might minimize or mitigate this potentially catastrophic complication.

## Methods

A comprehensive review of the literature was conducted. A meta-analysis was not performed due to the extreme heterogeneity of the diagnostic methodology and clinical reporting in the available literature. Additionally, there were no prospective, randomized clinical trials or any studies with design amenable for statistical data aggregation. Consequently, this review is reported as a narrative rather than meta-analysis. PubMed, MEDLINE, Google Scholar, and Cochrane Library were searched using the following keywords: mesh AND hernia AND (migration OR erosion) NOT (hiatus OR hiatal OR diaphragmatic). The clinical trial database clinicaltrials.gov was also reviewed. Letters to the editor were reviewed to extract possible cross-references. All abstracts were reviewed independently for inclusion by two authors (HC and SH). Relevant manuscripts were obtained for entire manuscript review and inclusion (Fig. 1). Mesh migration events after hiatal hernia mesh repairs were excluded from this analysis due to continued controversy over the use of mesh at the hiatus [21]. In fact, only a minority of surgeons use mesh routinely in the repair of hiatal hernias [22], and according to the Society of American Gastrointestinal and Endoscopic Surgeons Guidelines for Management of Hiatal Hernia, “there is inadequate long-term data on which to base a recommendation either for or against the use of mesh at the hiatus” [23].

## Definition of mesh migration

For this analysis, mesh migration was defined as mesh that resulted in invasion of any anatomical region other than the area intended for repair. All articles which reported mesh migration were analyzed. This included cases where mesh infection led to the involvement of intra-abdominal

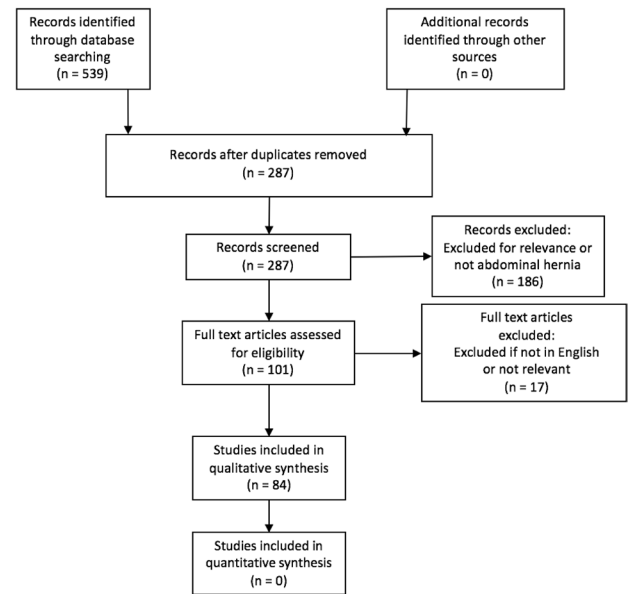


Fig. 1 Literature review consort diagram

organs. Mesh erosion is a term used frequently in the literature to describe any invasion of an organ by an entire or partial piece of mesh. As such, in this study, we also use the terms interchangeably.

## Definition of mesh position

Inguinal hernias were classified by description of mesh placement in each case report. The term “Lichtenstein”, was applied if the author specifically used this term or described positioning the mesh anterior to the transversalis fascia, often referred to as an onlay patch repair. Inguinal canal designation was used in cases describing mesh placement in the inguinal canal. Pre-peritoneal placement was used for all transabdominal pre-peritoneal (TAPP) and totally extra-peritoneal (TEP) inguinal hernia repairs. Intra-peritoneal placement was used when specifically noted or for intra-peritoneal onlay mesh (IPOM) operations. A Prolene Hernia System (PHS) (Ethicon, West Somerville, NJ) was given its own classification due to its multiplane involvement. Those which were not specified in the report were classified as unknown.

For classification of the remaining abdominal wall hernias, broad categories of intraperitoneal, extra-peritoneal, and unknown were employed. Intra-peritoneal included those meshes which were noted to be placed as such or labeled as IPOM. Pre-peritoneal, supra-peritoneal, sublay, and inlay descriptions were observed, reported, and included in the extra-peritoneal group.

## Definition of organ involvement

Organs were considered implicated in mesh migration when found to have been directly affected by the mesh itself. For example, a mesh migration resulting in a vesico-cutaneous fistula would be classified as multiple due to the involvement of both the bladder and skin. Furthermore, a mesh which migrated into the sigmoid colon also requiring bladder resection due to adhesions would be classified as multiple. Of note, mesh invading the distal small bowel but requiring a right hemicolectomy to facilitate re-anastomosis would be classified as involving the small bowel only. Finally, the mention of invasion of, erosion of, or adherence to any organs would also be considered involvement of each of those organs.

## Statistical analysis

No data aggregation was employed for analysis. All variables were tested for normality and expressed as mean  $\pm$  standard deviation (SD) or median  $\pm$  interquartile range (IQR) accordingly. All cases were extracted into an excel spreadsheet to avoid duplication of cases.

## Results

In total, 287 unique citations were reviewed and excluded if mesh was placed for a reason other than hernia of abdominal wall or pelvis. Articles were also excluded if they were not published in English. Ultimately, 84 articles were selected and consisted of three case series with or without literature review, 77 case reports, one retrospective study, one prospective, observational study, and two literature reviews (Fig. 1). No randomized controlled trials, meta-analysis or systematic reviews were found. Eighty-four articles yielded 89 cases. These articles were published between 1996 and 2017. The first case report of mesh migration was reported by Hume and Bour and described migration of mesh into the bladder after laparoscopic left inguinal hernia repair [14]. The first case series was published in 2011 by Kocot et al. and included two cases of mesh migration amongst four cases of unusual urologic complications after laparoscopic inguinal hernia repairs [24]. Sixteen reviews of the literature were analyzed including those published with a case report or series; however, the topics covered were variable. The first was published in 2004 by Riaz et al. [25]. Overall, publications describing mesh migration complications have increased over time (Fig. 2).

Overall, patient gender was reported in 80 instances with a 76.2% male predominance. The average patient age was  $59.8 \pm 13.8$  years with a range of 27 to 87 years. The index hernia repair for reported cases was inguinal in

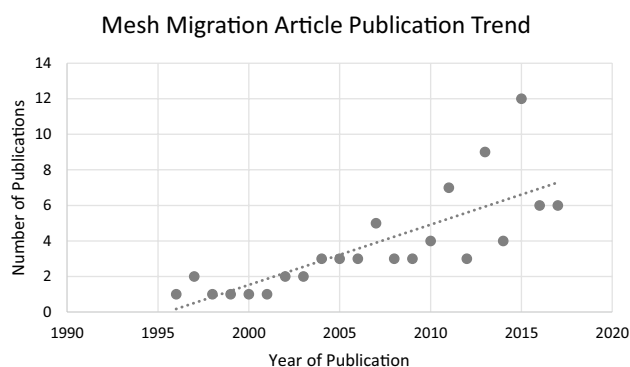


Fig. 2 Mesh migration report publication trend over time

## Anatomic Placement of Inguinal Hernia Mesh

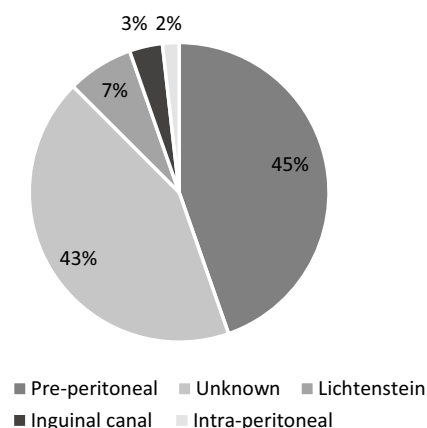


Fig. 3 Anatomic placement of inguinal hernia repair mesh

62.9%, incisional/ventral in 28.1%, umbilical in 6.7%, and 2.2% were lumbar or obturator. Within the inguinal hernia group, 51.8% were open repairs, 42.9% were laparoscopic, and 1.8% were robotic. The type of repair was unable to be determined in 3.6% of inguinal hernia patient reports. In all other index operation groups, the approach was open in 69.7% of cases, laparoscopic in 21.2% of cases, and unreported in 9.1% of cases.

Mesh material was not described in 39.3% of cases. Of the remaining 54 cases, 37 involved polypropylene mesh, six involved polytetrafluoroethylene (PTFE), and eight were composite meshes. Polyester fiber, polypropylene wrapped in vicryl, and stainless steel meshes were implicated in the remaining three cases. For inguinal hernia repairs, contribution of various anatomic placements is depicted in Fig. 3. In other abdominal wall hernia types, the anatomic locations reported for mesh placement included “inlay” for two cases, “sublay” for two cases, “preperitoneal” for two cases, and simply “extraperitoneal” and “supraperitoneal” for three and

one cases, respectively (Fig. 4). Mesh fixation techniques were largely unreported; however, the collected aggregate data are presented in Fig. 5. Mesh plugs were implicated in 23.6% of all patient cases. A majority of migration cases involved meshes with a non-plug configuration (74.2%). Use of plug was unable to be determined in 2.2% of cases. When evaluating inguinal hernia mesh migration cases, plugs were implicated in 35.7%, not used in 62.5%, and not specified in 1.8%.

Multiple organs were involved in 31.5% of cases. Small bowel was affected in 25.8% of reports. The colon and bladder were affected sites in 15 reports each (16.9% each). Other sites including skin, spermatic cord, scrotum, adnexa, heart, and general abdominal cavity accounted for the remaining 9% of anatomic mesh destinations. In cases classified as multiple, 19 were found to have fistulas at the time of presentation. Six were colo-cutaneous, six were entero-cutaneous, five were vesico-cutaneous, and two were colo-vesical fistulas. The remaining none cases involved two or more organ systems at the same presentation or at two different time points. An overwhelming majority of cases were managed operatively while a few were treated with endoscopic or cystoscopic intervention. Conservative measures were sufficient in five cases (Fig. 6). Of those patients who had surgery, 79% required resection of an organ. The operation was a laparotomy in 75.3% of all operative patients. Median time from index mesh placement to definitive diagnosis or treatment was 48 months (IQR = 24–93).

The presence or absence of hernia recurrence at the time of patient presentation with migration or erosion complication was also examined. Hernia recurrence was discovered in a significant portion of cases (28.1%) with a

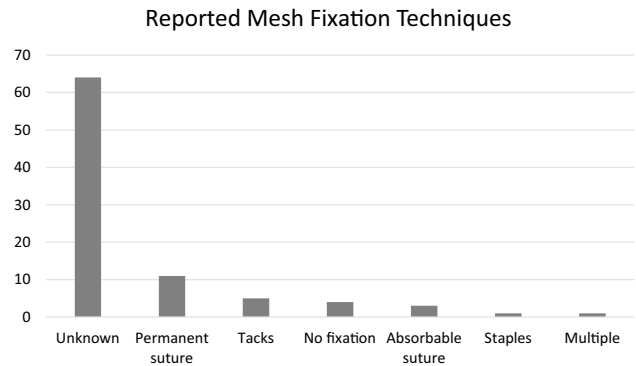


**Fig. 5** Reported mesh fixation techniques

majority of these treated surgically (80%). No recurrence was identified in 20.2% while the absence or presence of hernia recurrence was not reported in over half of cases (51.7%).

Clinical presentations widely varied depending on the anatomic destinations of mesh. For instance, one patient presented with cardiac insufficiency 24 h after implantation of a 30 × 50-cm plastic mesh for a large abdominal hernia [26]. In this case, a portion of the fixation system for the mesh had migrated through the diaphragm and pierced the pericardium injuring the right ventricle in several regions. This ultimately resulted in patient death. All reviewed cases are listed in Tables 1, 2, 3, 4 and 5, organized by the affected organ. Full citations for these articles can be found in Appendices A and B.

#### Anatomic Mesh Placement in Non-Inguinal Abdominal Hernia Repairs

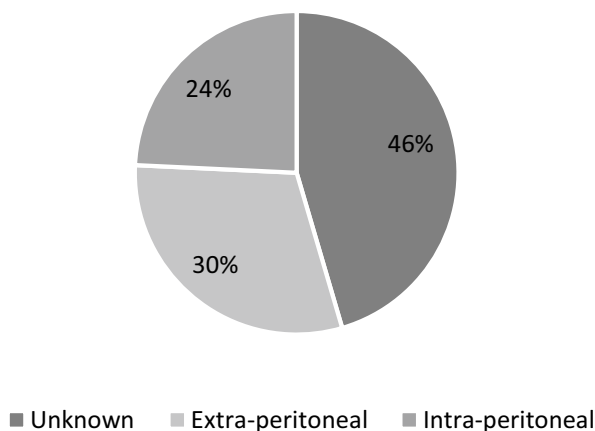


**Fig. 4** Anatomic placement of mesh in non-inguinal hernia repairs

#### Management of Mesh Migration Cases

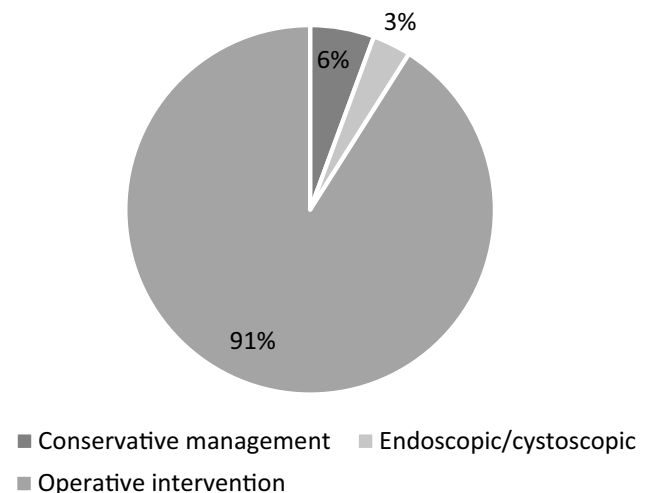


**Fig. 6** Classification of management types in mesh migration cases

**Table 1** Cases of mesh migration involving multiple organ systems

| Authors          | Year | Study type  | Index operation | Presentation     |
|------------------|------|-------------|-----------------|------------------|
| Ishikawa         | 2015 | Case report | Inguinal HR     | Abdominal pain   |
| Lauwers          | 2003 | Case report | Inguinal HR     | Colon mass       |
| Ramanathan       | 2017 | Case report | Inguinal HR     | CVF              |
| Miller           | 1997 | Case report | Inguinal HR     | ECF              |
| Al-Subaie        | 2015 | Case report | Inguinal HR     | ECF              |
| Sekiguchi        | 2015 | Case report | Inguinal HR     | ECF              |
| Kurukahvecioglu  | 2007 | Case report | Inguinal HR     | Hematuria        |
| Li               | 2014 | Case series | Inguinal HR     | Hematuria        |
| Hamouda          | 2010 | Case report | Inguinal HR     | Recurrent sepsis |
| Ojo              | 2006 | Case report | Inguinal HR     | RLQ mass         |
| Nowak            | 2005 | Case report | Inguinal HR     | SBO              |
| Barreto          | 2009 | Case report | Inguinal HR     | Sepsis           |
| Degheili         | 2015 | Case report | Inguinal HR     | Sepsis           |
| Aggarwal         | 2016 | Case report | Inguinal HR     | UTI              |
| Chowbey          | 2006 | Case report | Inguinal HR     | VCF              |
| Acar             | 2002 | Case report | Ventral HR      | ECF              |
| Ratajczak        | 2013 | Case report | Ventral HR      | ECF              |
| Su               | 2014 | Case report | Ventral HR      | EVF              |
| Horzic           | 2011 | Case report | Incisional HR   | Abdominal pain   |
| Norton           | 2016 | Case report | Incisional HR   | Diet intolerance |
| Fernandez Lobato | 2001 | Case report | Incisional HR   | ECF              |
| Sahoo            | 2013 | Case report | Incisional HR   | ECF              |
| Bostanci         | 2015 | Case report | Incisional HR   | ECF              |
| Malik            | 2015 | Case report | Incisional HR   | ECF              |
| Raghavendran     | 2017 | Case report | Incisional HR   | EVF              |
| Shrivastava      | 2013 | Case report | Incisional HR   | Peritonitis      |
| Bjurlin          | 2011 | Case report | Femoral HR      | Recurrent UTI    |
| Jha              | 2012 | Case report | Lumbar HR       | ECF              |

*HR* hernia repair, *ECF* entero-cutaneous fistula, *CVF* colo-vesical fistula, *UTI* urinary tract infection, *SBO* small bowel obstruction, *VCF* vesico-cutaneous fistula, *RLQ* right lower quadrant

## Discussion

As mesh repairs continue to gain popularity, reports of migration have also become more common with almost 40 articles published in the past 5 years (Fig. 2). Reports are heterogeneous and highlight the diverse mesh types implicated, clinical presentations observed, and diagnostic and therapeutic tools employed. This study sought to review the available literature and define the best clinical practices which might minimize or mitigate this potentially catastrophic complication. The mesh migration body of literature consists primarily of case reports and case series with a single prospective, observational study and one retrospective review. As a result, the true rate of this complication is

**Table 2** Cases of mesh migration involving small bowel

| Authors    | Year | Study type  | Index operation | Presentation   |
|------------|------|-------------|-----------------|----------------|
| Moorman    | 2004 | Case report | Inguinal HR     | Abdominal pain |
| Chen       | 2010 | Case report | Inguinal HR     | Acute abdomen  |
| Stout      | 2007 | Case report | Inguinal HR     | SB volvulus    |
| Yamamoto   | 2015 | Case report | Inguinal HR     | SBO            |
| Xue        | 2015 | Case report | Inguinal HR     | SBO            |
| Tiwari     | 2014 | Case report | Inguinal HR     | SBO            |
| Lo         | 2008 | Case report | Inguinal HR     | SBO            |
| Liang      | 2008 | Case report | Inguinal HR     | SBO            |
| Ferrone    | 2003 | Case report | Inguinal HR     | SBO            |
| Chuback    | 2000 | Case report | Inguinal HR     | SBO            |
| Borchert   | 2008 | Case report | Obturator HR    | SBO            |
| Ratajczak  | 2013 | Case report | Ventral HR      | ECF            |
| Nelson     | 2011 | Case report | Ventral HR      | ECF            |
| Voisard    | 2013 | Case report | Incisional HR   | Chronic anemia |
| Falk       | 2009 | Case report | Incisional HR   | Gastric mass   |
| Olmi       | 2013 | Case report | Incisional HR   | SBO            |
| Steinhagen | 2010 | Case report | Incisional HR   | SBO            |
| Majeski    | 1998 | Case report | Incisional HR   | SBO            |
| Ripetti    | 2013 | Case report | Umbilical HR    | ECF            |
| Perumal    | 2016 | Case report | Umbilical HR    | SBO            |
| Bagul      | 2015 | Case report | Umbilical HR    | SBO            |
| Barnes     | 2012 | Case report | Umbilical HR    | SBO            |
| Di Muria   | 2007 | Case report | Umbilical HR    | SBO            |

*HR* hernia report, *SBO* small bowel obstruction, *ECF* entero-cutaneous fistula, *SB* small bowel

unknown. This is compounded by the possibility that mesh migration is under-reported in the literature.

The current study found that there was an insufficient reporting of mesh material, anatomic placement, and fixation techniques as well as the wide range of time interval between an index hernia repair with mesh to time of mesh migration complication. With a paucity of quality data at this time, guidelines for practice are unable to be firmly established. Inconsistent nomenclature for the planes of abdominal wall hernia repairs with mesh complicate reporting and interpretation of mesh migration [27]. Additionally, the authors submit that the definitions of mesh migration and erosion be standardized for increased clarity in reporting. Ideally, these definitions would be based on etiology of mesh movement; however, this is often unknown or multifactorial in nature and, therefore, a more meaningful definition may relate to the complete or incomplete involvement of mesh movement into another organ. We assert that the previously discussed definition of “mesh migration” as whole mesh displaced into an organ and “mesh erosion” as partial mesh perforation into an organ while a portion remains outside the organ should be reliably used when describing these complications. Additionally, a related but unique term of “mesh

**Table 3** Cases of mesh migration involving bladder

| Authors      | Year | Study type           | Index operation | Presentation   |
|--------------|------|----------------------|-----------------|----------------|
| Jensen       | 2004 | Case report          | Inguinal HR     | Bladder stones |
| Sevilla      | 2017 | Case report          | Inguinal HR     | Bladder tumor  |
| Novaretti    | 2012 | Case report          | Inguinal HR     | Bladder tumor  |
| Sandhu       | 2017 | Case report          | Inguinal HR     | Hematuria      |
| Funada       | 2016 | Case report          | Inguinal HR     | Hematuria      |
| Li           | 2014 | Case report          | Inguinal HR     | Hematuria      |
| Kocot        | 2011 | Case report          | Inguinal HR     | Hematuria      |
| Savioz       | 1997 | Case report          | Inguinal HR     | Hematuria      |
| Hume         | 1996 | Case report          | Inguinal HR     | Hematuria      |
| Kocot        | 2011 | Case report          | Inguinal HR     | Hydronephrosis |
| Nikhil       | 2013 | Case report          | Inguinal HR     | LUTS           |
| Ramakrishnan | 2016 | Retrospective review | Inguinal HR     | NR             |
| Agrawal      | 2006 | Case report          | Inguinal HR     | Recurrent UTI  |
| Graziano     | 2007 | Case report          | Incisional HR   | Hematuria      |
| Riaz         | 2004 | Case report          | Incisional HR   | Hematuria      |

*HR* hernia repair, *NR* not reported, *LUTS* lower urinary tract symptoms, *UTI* urinary tract infection

**Table 4** Cases of mesh migration involving the colon

| Authors      | Year | Study type                 | Index operation | Presentation           |
|--------------|------|----------------------------|-----------------|------------------------|
| Benedetti    | 2005 | Case report                | Inguinal HR     | Abdominal pain         |
| Yilmaz       | 2013 | Case report                | Inguinal HR     | BO                     |
| Na           | 2017 | Case report                | Inguinal HR     | Colon tumor            |
| Chan         | 2017 | Case report                | Inguinal HR     | Colon tumor            |
| Ratajczak    | 2013 | Prospective, observational | Inguinal HR     | Colon tumor            |
| Goswami      | 2007 | Case report                | Inguinal HR     | Diarrhea               |
| Celik        | 2005 | Case report                | Inguinal HR     | Diarrhea               |
| Karls        | 2011 | Case report                | Inguinal HR     | GIB                    |
| Hakam        | 2010 | Case report                | Inguinal HR     | GIB                    |
| Ramakrishnan | 2016 | Retrospective review       | Inguinal HR     | NR                     |
| Ramakrishnan | 2016 | Retrospective review       | Inguinal HR     | NR                     |
| Millas       | 2015 | Case report                | Ventral HR      | Chronic abdominal pain |
| Aziz         | 2014 | Case report                | Incisional HR   | Chronic abdominal pain |
| Gandhi       | 2011 | Case report                | Incisional HR   | Chronic abdominal pain |
| Fukudome     | 2014 | Case report                | Incisional HR   | Epigastralgia          |

*HR* hernia repair, *BO* bowel obstruction, *NR* not reported, *GIB* gastrointestinal bleed

**Table 5** Cases of mesh migration involving other organs

| Authors     | Year | Study type  | Index operation | Presentation               |
|-------------|------|-------------|-----------------|----------------------------|
| Scheuer     | 2015 | Case report | Inguinal HR     | Abdominal mass             |
| Rettenmaier | 2009 | Case report | Inguinal HR     | Adenaxal mass              |
| Bhullar     | 2013 | Case report | Inguinal HR     | Groin mass                 |
| Ismail      | 2002 | Case report | Inguinal HR     | Recurrent groin infections |
| Maffi       | 2016 | Case report | Inguinal HR     | Scrotal mass               |
| Dieter      | 1999 | Case report | Inguinal HR     | Scrotal mass               |
| Ripetti     | 2013 | Case report | Umbilical HR    | Externalization of mesh    |
| Endlich     | 2015 | Case report | Abdominal HR    | Cardiac insufficiency      |

*HR* hernia repair

dislodgement” should be applied when mesh movement causes a recurrence of hernia but without the involvement of another organ system or body region. This may be further divided into “partial” and “complete” mesh dislodgement.

This is the first comprehensive review of the topic of mesh migration. While there are several literature reviews available [17, 18, 20, 25, 28–32], these are certainly not comprehensive as they discuss a narrow aspect of presentation, mesh material, anatomic destination, or noteworthy management of mesh migration. While no statistical analysis could be performed, the descriptive statistics provided aim to guide future authors in which factors should be addressed in reports. Undoubtedly, some of the deficiencies in reporting are related to an inability to obtain records for patients who did not undergo their index operation at the same institution that they had their mesh migration addressed.

Multiple hypotheses have been proposed for mesh migration. Agrawal et al. categorized migrations into primary and secondary types [19]. Primary mesh migration occurs when a mesh moves along anatomic planes which provide very little resistance. This may be due to inadequate fixation or external forces which promote movement. Secondary migration is characterized by a gradual, trans-anatomic movement. Foreign body reactions then lead to erosion through tissues. In the present report, it was difficult to ascertain whether the fixation of mesh was a contributory factor to migration due to the high level of non-reporting (Fig. 5).

The question of the need for fixation in both open and laparoscopic groin hernia repair with mesh has been investigated previously. Most recently, the HerniaSurge Group published International Guidelines for Groin Hernia Management in 2018 with an entire chapter dedicated to the issue of mesh fixation [33]. With regard to open groin hernia repairs, newer options such as fibrin glue and self-fixating meshes were found to be viable alternatives to suture fixation in terms of recurrence at 1 year and were found to reduce post-operative pain. Interestingly, in laparoscopic groin hernia repairs, non-fixation of mesh was recommended for all hernia types with the exception of large medial defects. Recurrence and post-operative pain did not differ between fixation and non-fixation for TEP and TAPP; however, a significant reduction in operative time was noted in the non-fixation group. The implications of these techniques for the risk of mesh migration are not yet known, and improvements in reporting will be instrumental in building a better understanding of this phenomenon.

Another set of contributing factors leading to migration were identified by Ismail et al. [34]. In this case report, the authors describe a patient who underwent multiple open inguinal hernia repairs which were complicated by recurrent groin infections. Eventually, the patient presented with mesh which externalized through the skin, and an exploration of the groin was performed with removal of the mesh.

The patient’s clinical course was attributed to the chronic inflammatory process, the placement of an undersized mesh causing increased tension, and the intraoperative finding of mesh tails which had conformed into a cone shape possibly predisposing the mesh to migration. In our review, a significant proportion of reported cases involved a history of plug-in hernia repair; however, the overwhelming majority of cases described the migration of multiple mesh shapes.

It is well recognized that the placement of prosthetic mesh for hernia repair results in a higher inflammatory response than tissue repair [35], and several studies have investigated the responses between mesh types. In a rabbit model of intra-peritoneal inguinal hernia repair, polypropylene developed significantly more adhesions over a 16-week period relative to expanded PTFE [36]. Furthermore, when compared to two different composite meshes, expanded PTFE has been found to result in fewer adhesions [37] but increased shrinkage [38] possibly related to a lower rate of tissue ingrowth [39]. Considering that adhesions may promote erosion between mesh and tissue planes, but that shrinkage may also encourage movement along anatomic planes, optimal mesh material has not yet been established. Additionally, shrinkage of mesh placed for hernia repair and fixed by permanent measures could result in increased tension on the mesh, and increased tension has been suggested as a possible source of migration predisposition as mentioned above [34]. Among the reviewed articles, polypropylene was the most commonly reported material in migration cases; however, it is important to note that this is likely because it is very commonly used by surgeons, particularly in Lichtenstein hernia repairs. It is noteworthy that no biologic meshes or absorbable meshes were directly implicated in any of the case reports reviewed, although they were used to treat patient hernias in several cases after index mesh was removed. The reason for a lack association between biologic or absorbable mesh types and migration or erosion is likely multifactorial. First, these materials are newer and less commonly used leading to a lower likelihood of having seen and reported this rare complication. Second, the mesh material was not reported or not able to be identified in a significant portion of cases. And so, it is possible these materials were associated with migration or erosion but were not identified as such. Finally, these mesh types may confer an advantage with regard to migration predisposition. This, however, remains to be determined in the literature. Similarly, these points of discussion may also apply to novel approaches to hernia repair with mesh placement such as Transversus Abdominis Muscle Release which were not implicated in any of the reported cases.

Due to the wide range of reporting in mesh migration, the optimal management of patients affected by this clinical entity has not been established. For now, the decision for mesh treatment should be individualized to a patient’s

symptoms, their clinical presentation, and technical considerations such as the involvement of high-risk areas [24, 40] as well as the overall condition of the patient. This study is limited by the quality of the existing literature. Mesh migration is an uncommon complication of mesh hernia repair which can have grave consequences [42, 43]. As a result of its low incidence, no study has reported more than three mesh migration cases [41, 43]. The nature of these studies lends the data to a large publication bias, and we recognize that the generalizability of the conclusions of the reported cases and any recommendations based on the data need to be interpreted with caution. The purpose of including these numbers is to provide clinicians with a template of suggested variables for inclusion in their reports and to emphasize the wide range of effects that mesh migration can have on patients. Ideally, this will generate more detailed descriptions of migration cases leading to a better understanding of the factors which contribute to this entity as well as encourage physicians to include mesh migration on a differential for a much broader set of presentations.

At this juncture, it appears that inguinal hernias are the most common type of hernias leading to mesh migration. However, this might be a reflection of this being one of the most common hernia repairs. This is also the case for the material used for repair. This study found that there is no hernia repair or material that is immune to this complication. In futures studies, the authors will aim to retrospectively collect data on abdominal hernia mesh repairs from multiple institutions. We also hope to create and maintain a prospective dataset at each of the participating sites to contribute higher quality data on this topic. We hope that this review will serve as a staging platform for other authors to publish cases of mesh migration with more complete descriptive details such as

1. precise anatomic location of original hernia defect;
2. precise size of original hernia defect;
3. index hernia repair type;
4. specific mesh material used;
5. precise anatomic location of mesh placement (e.g., retro-rectus, intra-peritoneal on-lay, etc.);
6. mesh fixation technique including material or device used;
7. precise size of mesh placed;
8. proposed etiology for migration or erosion;
9. detailed account of any previous hernia repairs and mesh placements in that patient with similar levels of detail as listed above;
10. patient's clinical presentation (e.g., nausea, vomiting, pain, rectal bleeding, fatigue, etc.) with timeframe of symptoms;
11. clinical findings (e.g., small bowel obstruction, bladder tumor, scrotal mass, etc.);

12. operative findings (e.g., partial mesh still in place, colo-vesical fistula, adhesions distant from the migrated mesh destination suggesting etiology for presentation, etc.);
13. discussion of status of initially treated hernia (the presence or absence of hernia recurrence);
14. length of time between mesh placement and migration or erosion complication;
15. precise size of migrated or explanted mesh (to evaluate for evidence of mesh shrinkage);
16. management.

This list should serve as a reference recognizing that all cases may not have all of this information available and as a reminder that an effort should be made to gather and report these details when possible. More importantly, this study's results should highlight a need for a multi-institutional approach to data collection to draw more clinically significant conclusions regarding the best ways to decrease the risk of this complication and improve our ability to predict those patients at highest risk.

## Conclusions

While mesh migration is uncommon, mesh repair of abdominal hernias continues to gain popularity, and as such, physicians should expect to care for increasing numbers of patients with this complication. Currently, the literature on this topic is lacking in many regards, and reporting clinicians may benefit from a more standardized set of publication requirements which would better inform other treating physicians. Overall, this review highlights that mesh migration is a diverse issue with many possible contributing factors, clinical presentations, and management options.

## Compliance with ethical standards

**Conflict of interest** HC declares no conflict of interest. JW declares no conflict of interest. LT declares no conflict of interest. SH declares no conflict of interest.

**Ethical approval** This study is in compliance with ethical standards.

**Human and animal rights** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** For this type of study, formal consent is not required.

## References

1. Dabbas N et al (2011) Frequency of abdominal wall hernias: is classical teaching out of date? *JRSM Short Rep* 2(1):5

2. Rutkow IM (1998) Epidemiologic, economic, and sociologic aspects of hernia surgery in the United States in the 1990s. *Surg Clin North Am* 78(6):941–941 51, v–vi
3. Rutkow IM (1997) Surgical operations in the United States. Then (1983) and now (1994). *Arch Surg* 132(9):983–990
4. Rutkow IM (2003) Demographic and socioeconomic aspects of hernia repair in the United States in 2003. *Surg Clin North Am* 83(5):1045–1051
5. Shouldice EB (2003) The Shouldice repair for groin hernias. *Surg Clin North Am* 83(5):1163–1187, vii
6. Burger JW et al. (2004) Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg* 240(4): 578–583 (discussion 583–5)
7. Arroyo A et al (2001) Randomized clinical trial comparing suture and mesh repair of umbilical hernia in adults. *Br J Surg* 88(10):1321–1323
8. Luijendijk RW et al (2000) A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med* 343(6):392–398
9. Aldridge AJ, Nehra D (2001) Mesh compared with non-mesh methods of open groin hernia repair: systematic review of randomized controlled trials and laparoscopic compared with open methods of groin hernia repair: systematic review of randomized controlled trials. *Br J Surg* 88(3):471
10. Amid PK, Shulman AG, Lichtenstein IL (1994) A critical evaluation of the Lichtenstein tension-free hernioplasty. *Int Surg* 79(1):76–79
11. Fitzgibbons RJ Jr, Forse RA (2015) Clinical practice. Groin hernias in adults. *N Engl J Med* 372(8):756–763
12. Berger RL et al (2014) Suture versus preperitoneal polypropylene mesh for elective umbilical hernia repairs. *J Surg Res* 192(2):426–431
13. Ghanim A et al (2017) Mesh Migration into the j-pouch in a patient with post-ulcerative colitis colectomy: a case report and literature review. *Case Rep Surg* 2017:3617476
14. Hume RH, Bour J (1996) Mesh migration following laparoscopic inguinal hernia repair. *J Laparoendosc Surg* 6(5):333–335
15. Chuback JA et al (2000) Small bowel obstruction resulting from mesh plug migration after open inguinal hernia repair. *Surgery* 127(4):475–476
16. Dieter RA Jr (1999) Mesh plug migration into scrotum: a new complication of hernia repair. *Int Surg* 84(1):57–59
17. Xue TM et al (2015) Mesh erosion causes small bowel obstruction: a rare complication of laparoscopic inguinal hernia repair: case description and review of literature. *Hepatogastroenterology* 62(137):55–58
18. Celik A et al (2005) Colonoscopic removal of inguinal hernia mesh: report of a case and literature review. *J Laparoendosc Adv Surg Tech A* 15(4):408–410
19. Agrawal A, Avill R (2006) Mesh migration following repair of inguinal hernia: a case report and review of literature. *Hernia* 10(1):79–82
20. Goswami R, Babor M, Ojo A (2007) Mesh erosion into caecum following laparoscopic repair of inguinal hernia (TAPP): a case report and literature review. *J Laparoendosc Adv Surg Tech A* 17(5):669–672
21. Hinojosa MW, Wright AS, Oelschlagel BK (2015) The use of mesh in hiatal hernia repair. In: *Antireflux surgery*. Springer, New York
22. Pfluke JM et al (2012) Use of mesh for hiatal hernia repair: a survey of SAGES members. *Surg Endosc* 26(7):1843–1848
23. Kohn GP et al (2018) Guidelines for the management of hiatal hernia. [Webpage]. Available at: <https://www.sages.org/publications/guidelines/guidelines-for-the-management-of-hiatal-hernia/>. Accessed 6 Aug 2018
24. Kocot A, Gerharz EW, Riedmiller H (2011) Urological complications of laparoscopic inguinal hernia repair: a case series. *Hernia* 15(5):583–586
25. Riaz AA et al (2004) Mesh erosion into the bladder: a late complication of incisional hernia repair. A case report and review of the literature. *Hernia* 8(2):158–159
26. Endlich M et al (2015) Implantation of a total abdominal mesh plastic ending up in multiple, lethal right heart injuries. *Interact Cardiovasc Thorac Surg* 21(1):135–136
27. Parker SG et al (2017) Nomenclature in abdominal wall Hernias: is It time for consensus? *World J Surg* 41(10):2488–2491
28. Lo DJ, Bilimoria KY, Pugh CM (2008) Bowel complications after prolene hernia system (PHS) repair: a case report and review of the literature. *Hernia* 12(4):437–440
29. Millas SG, Mesar T, Patel RJ (2015) Chronic abdominal pain after ventral hernia due to mesh migration and erosion into the sigmoid colon from a distant site: a case report and review of literature. *Hernia* 19(5):849–852
30. Gandhi D et al (2011) Chronic abdominal pain secondary to mesh erosion into cecum following incisional hernia repair: a case report and literature review. *Ann Gastroenterol* 24(4):321–324
31. Jeans S, Williams GL, Stephenson BM (2007) Migration after open mesh plug inguinal hernioplasty: a review of the literature. *Am Surg* 73(3):207–209
32. Acar T et al (2002) Enterocutaneous fistula due to polypropylene mesh migration. *Ir J Med Sci* 171(3):172, 174
33. HerniaSurge G (2018) International guidelines for groin hernia management. *Hernia* 22(1):1–165
34. Ismail W, Agrawal A, Zia MI (2002) Fate of chronically infected onlay mesh in groin wound. *Hernia* 6(2):79–81
35. Di Vita G et al (2000) Tension-free hernia repair is associated with an increase in inflammatory response markers against the mesh. *Am J Surg* 180(3):203–207
36. Matthews BD et al (2003) Assessment of adhesion formation to intra-abdominal polypropylene mesh and polytetrafluoroethylene mesh. *J Surg Res* 114(2):126–132
37. Matthews BD et al (2005) Evaluation of adhesion formation and host tissue response to intra-abdominal polytetrafluoroethylene mesh and composite prosthetic mesh. *J Surg Res* 123(2):227–234
38. Harrell AG et al (2006) Prospective evaluation of adhesion formation and shrinkage of intra-abdominal prosthetics in a rabbit model. *Am Surg* 72(9):808–813 (**discussion 813–4**)
39. Gonzalez R et al (2005) Relationship between tissue ingrowth and mesh contraction. *World J Surg* 29(8):1038–1043
40. Ferrone R, Scarone PC, Natalini G (2003) Late complication of open inguinal hernia repair: small bowel obstruction caused by intraperitoneal mesh migration. *Hernia* 7(3):161–162
41. Ramakrishnan P et al (2016) A single-centre experience of relaparoscopy in complications of laparoscopic inguinal hernia repair: feasibility and outcomes. *Surg Endosc* 30(6):2308–2314
42. Shrivastava A et al (2013) Erosion of small intestine with necrotising fasciitis of over lying abdominal wall after expanded poly-tetrafluoroethylene mesh implantation: a rare complication after laparoscopic incisional hernia repair. *J Minim Access Surg* 9(3):138–140
43. Ratajczak A et al (2013) Migration of biomaterials used in gastroenterological surgery. *Pol Przegl Chir* 85(7):377–380

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.