A REVIEW OF INCIDENCE, RISK FACTORS, AND MANAGEMENT OF CHYLE LEAK FOLLOWING ABDOMINAL SURGERY

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ABSTRACT
Chyle leak (CL) is an uncommon complication of abdominal surgery; the true incidence is difficult to appreciate. Unlike other complications, CL is poorly described, and current treatment options are largely not evidence-based. This article aims to review the incidence, aetiology and risk factors associated with CL following abdominal procedures and propose a management algorithm. We performed a search of multiple databases and identified studies on CL following abdominal procedures. The data was compiled and used to identify high-risk procedures and risk factors for CL.

Incidence was highly variable between studies and was highest following pancreatic resection and retroperitoneal lymph node dissection. No high-quality studies have calculated the incidence of CL following several commonly performed abdominal operations, e.g. hepatectomy. Numerous studies identified the number of resected lymph nodes, the number of involved lymph nodes and retroperitoneal dissection as independent risk factors. Optimum management remains a source of debate. Most cases of CL are self-limiting and will resolve within 2-3 weeks following conservative measures alone. Severe cases can result in increased length of stay and have metabolic, immunologic, and economic implications. Following diagnosis of CL, we advise starting patients on octreotide and commencing a low-fat medium-chain triglyceride-based diet. If this fails, then total parenteral nutrition can be considered. Novel minimally invasive techniques and surgical options should be kept as a last resort for those with significant complications, or those who have failed a non-operative approach.

KEYWORDS
Chyle Leak, Chylous Ascites, Abdominal, Surgery, Resection, Management

Background
Chyle leak (CL) is an uncommon complication of major abdominal surgery. Unlike other recognised complications, its definition, incidence, and clinical relevance are poorly described. It is becoming more frequent with the rise of laparoscopic techniques, more aggressive oncological resections, and increased overall survival. The true incidence is difficult to appreciate due to differing definitions amongst authors, the presence of subclinical cases, and the limited number of high-quality studies [1-4]. CL can result in significant morbidity, increased length of stay, and higher treatment costs [5,6]. Optimum management remains debated, and current treatment options are not evidence-based. This article aims to review the incidence, aetiology and risk factors associated with CL following major abdominal procedures, and propose a management algorithm. The management of CL following thoracic procedures will not be discussed in this article.
Definition

Chyle leak can be defined as the discharge of milky, lipid-rich (>110mg/dL) fluid from a surgical wound or drain, which is >100ml/day in quantity; the fluid must be non-infective and amylase free [7]. Having said this, there is considerable variation in the definition amongst authors. The term chylous ascites (CA), or chyloperitoneum, generally refers to the diffuse fluid within the abdominal cavity, rather than a local leak. However, this term is sometimes used interchangeably with CL. CA develops when there are a CL and no route for the lymph to exit the abdomen. Chyloretroperitoneum refers to the accumulation of chyle in the retroperitoneal space; this is exceptionally rare [8]. Chylothorax refers to the presence of chyle within the chest cavity, seldom seen following abdominal surgery.

Aetiology

The lymphatic system is a network of tissues and organs which has an important role in fluid balance, immune function, and the absorption of fats and fat-soluble vitamins [9]. Lymphatics are blind-ended tubular structures which continuously collect interstitial fluid and ultimately return this fluid to the subclavian veins via the primary lymph vessel; the thoracic duct [10]. The cisterna chyli is a saccular retro-peritoneal structure which marks the termination of the retroperitoneal lymphatic pathways. It is located between the abdominal aorta and the bodies of the first and second lumbar vertebrae (Figure 1). It acts as a conduit for the lipid products of digestion as it collects fatty chyle from the intestines and passes this on to the thoracic duct [10]. Smaller fatty acids will pass from the intestinal lumen directly into the portal venous system. Larger fatty acids, i.e. those greater than ten carbon atoms in length, are absorbed by the lymphatic capillaries of the intestines and form chylomicrons. Chyle, which is bacteriostatic due to the high number of lymphocytes present, is formed from chylomicrons and lymph. Postoperative CL results from the intra-operative disruption of the thoracic duct, cisterna chyli, or major tributaries [9]. CL is well described following surgery to the neck and thorax [11,12]. In this case, the most common cause is an inadvertent injury to the thoracic duct [11]. The origin of the thoracic duct is the twelfth thoracic vertebrae, and hence direct injury is unlikely without entering the chest cavity.

Incidence and risk factors

Due to differing definitions amongst authors and underdiagnosis due to subclinical cases, the true incidence of CL following major abdominal surgery is unknown. As such, one must interpret the risk factors mentioned in the literature with caution. Furthermore, CL will often be associated with other major complications. Following univariate analysis, Strobel et al. concluded that pre-operative diabetes is the only patient-related factor associated with CL in those who undergo pancreatic resection [13]. Following a systematic review, Weniger et al. concluded that the extent of abdominal surgery is the main predictor of CL [14]. The risk of CL is, therefore increased in those with advanced disease who require extensive resections.

Some authors have argued that CL is more likely following laparoscopic surgery than open surgery; however, there is limited high-quality data which backs up this claim. Monopolar, bipolar, and ultrasound coagulation are all thought to disrupt lymphatic channels [3]. Additionally, laparoscopic surgery is associated with a higher rate of unrecognised lymphatic injury since lymphatic leakage may be overlooked due to pneumoperitoneum [8]. The incidence and risk factors associated with CL following major abdominal and retroperitoneal procedures are summarised in Table 1.

Hepatobiliary and pancreatic surgery

Hepatectomy:

Chyle leak is very rare following hepatic resection and living donor hepatectomy; only a handful of cases have been described [15]. To our knowledge, there are no high-quality studies which describe incidence or effect on the outcome.

Liver transplant surgery:

The incidence of CL in recipients following liver transplant is between 4.7% and 6.3%. Yilmaz et al. report an incidence of 4.7% in a series of 516 patients [16]. Univariate analysis revealed low albumin (P=0.04), the presence of pre-operative ascites (P=
Table 1 Incidence of chyle leak following commonly performed abdominal and retroperitoneal procedures. LVSS = LigaSure Vessel Sealing System, PA = para-aortic, SMA = superior mesenteric artery, PD = pancreatico-duodenectomy, RPLND = retroperitoneal lymph node dissection, PLND = pelvic lymph node dissection, AAA = abdominal aortic aneurysm.

<table>
<thead>
<tr>
<th>Speciality</th>
<th>Type of surgery</th>
<th>Incidence</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatobiliary and pancreatic surgery</td>
<td>Hepatectomy</td>
<td>Insufficient data to estimate</td>
<td>Not identified</td>
</tr>
<tr>
<td></td>
<td>Liver transplant [16,17]</td>
<td>4.7% – 6.3%</td>
<td>• Pre-op low albumen&lt;br&gt;• Pre-op ascites&lt;br&gt;• Use of LVSS for perihepatic dissection&lt;br&gt;• Younger age&lt;br&gt;• Low weight</td>
</tr>
<tr>
<td></td>
<td>Pancreatic resection [19,20]</td>
<td>1.0% – 16.3%</td>
<td>• PA area manipulation&lt;br&gt;• SMA root area manipulation&lt;br&gt;• Retroperitoneal invasion&lt;br&gt;• Focal chronic pancreatitis&lt;br&gt;• Early enteral feeding&lt;br&gt;• Pre-existing diabetes&lt;br&gt;• Resection for malignancy&lt;br&gt;• Increased operative time&lt;br&gt;• Concurrent pancreatic abscess/fistula&lt;br&gt;• Distal pancreatectomy &gt; PD</td>
</tr>
<tr>
<td>Oesophago-gastric surgery</td>
<td>Gastrectomy [21,22]</td>
<td>2.0% – 4.17%</td>
<td>• No. of resected nodes&lt;br&gt;• No. of involved nodes&lt;br&gt;• Tumour N stage</td>
</tr>
<tr>
<td></td>
<td>Bariatric surgery</td>
<td>Insufficient data to estimate</td>
<td>Not identified</td>
</tr>
<tr>
<td></td>
<td>Anti-reflux surgery</td>
<td>Insufficient data to estimate</td>
<td>Not identified</td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>Resection for colon cancer [28,29]</td>
<td>1.47% – 7.7%</td>
<td>• R hemicolectomy &gt; L hemicolectomy&lt;br&gt;• Tumour size&lt;br&gt;• Tumour location&lt;br&gt;• No. of resected nodes&lt;br&gt;• Increased age&lt;br&gt;• Experience of surgeon</td>
</tr>
<tr>
<td></td>
<td>Resection for rectal cancer [5]</td>
<td>2.8%</td>
<td>Not identified</td>
</tr>
<tr>
<td>Urological surgery</td>
<td>Nephrectomy [33,34]</td>
<td>0.77% – 5.1%</td>
<td>• L sided surgery &gt; R sided surgery&lt;br&gt;• Lymphadenectomy</td>
</tr>
<tr>
<td></td>
<td>RPLND [36,37]</td>
<td>1.5% – 7.0%</td>
<td>• Preoperative chemo&lt;br&gt;• Increased intra-op blood loss</td>
</tr>
<tr>
<td></td>
<td>PLND</td>
<td>Insufficient data to estimate</td>
<td>Not identified</td>
</tr>
<tr>
<td></td>
<td>Donor nephrectomy [39,40]</td>
<td>0.29% – 2.25%</td>
<td>Not identified</td>
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<tr>
<td></td>
<td>Renal transplant</td>
<td>Insufficient data to estimate</td>
<td>Not identified</td>
</tr>
<tr>
<td></td>
<td>Resection for nephroblastoma [44]</td>
<td>Insufficient data to estimate</td>
<td>• Extensive lymph node dissection above the level of the renal hilum</td>
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In a study involving 1921 patients, Pan et al. demonstrated an incidence of 2.6%; multivariate analysis demonstrated that para-aortic (PA) and superior mesenteric artery (SMA) root area dissection, retroperitoneal invasion, focal chronic pancreatitis, and early enteral feeding were all independent risk factors [2]. CL was more common following distal pancreatectomy than PD, and no significant difference was found between open and laparoscopic approaches [2]. In a larger study involving 3324 patients, Strobel et al. demonstrated an incidence of 10.4% [13]. The univariate analysis concluded that pre-existing diabetes, resection for malignancy, increased operative time, and concurrent pancreatic abscess or fistula were independent risk factors [13]. CL was shown to be associated with increased length of stay but was not associated with further morbidity or mortality [13].

To our knowledge, no large study has specifically compared CL rates in those who have undergone PD with PV reconstruction, and those who have undergone straightforward PD. Abu Hilal et al. studied a series of 245 patients who underwent major pancreatic resection and 40 (16.3%) experienced postoperative CL [20]. Portal vein reconstruction was undertaken in 4 cases (2.0%) in the non-CL group and in 3 cases (7.5%) in the CL group [20]. It is likely that PV reconstruction results in additional lymphatic disruption and increases the risk of CL, although this has not been proven.

### Table 2: Classification of chyle leak as per International Study Group on Pancreatic Surgery [7].

<table>
<thead>
<tr>
<th>Classification</th>
<th>Treatment required</th>
</tr>
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<tbody>
<tr>
<td>A (least invasive)</td>
<td>No specific intervention other than oral dietary restrictions</td>
</tr>
<tr>
<td>B</td>
<td>Prolongation of hospital stay, nasoenteral nutrition with dietary restriction, TPN, octreotide, maintenance of surgical drains, or placement of new percutaneous drains</td>
</tr>
<tr>
<td>C (most invasive)</td>
<td>Need for more invasive treatment, intensive care unit admission, or mortality</td>
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Pancreatic surgery:

Due to the position of the pancreas and its anatomical relations, CL post pancreatic resection is relatively common when compared with other major abdominal procedures. Incidence has been cited as low as 1.0% [19] and as high as 16.3% [20]. Incidence has risen as the number of extensive resections has increased [2]. In our study involving 560 patients who underwent a pancreaticoduodenectomy (PD), we identified 17 patients (3.04%) who developed postoperative CL (unpublished). Those who developed CL had higher BMI (P = 0.02), longer operative time (P = 0.03), higher rate of portal vein (PV) tumour adherence (P = 0.16), and more commonly underwent PV resection (P = 0.27). Although the latter two findings were not statistically significant, this is likely due to the low number of CL cases.

In a study involving 1921 patients, Pan et al. demonstrated an incidence of 2.6%; multivariate analysis demonstrated that para-aortic (PA) and superior mesenteric artery (SMA) root area dissection, retroperitoneal invasion, focal chronic pancreatitis, and early enteral feeding were all independent risk factors [2]. CL was more common following distal pancreatectomy than PD, and no significant difference was found between open and laparoscopic approaches [2]. In a larger study involving 3324 patients, Strobel et al. demonstrated an incidence of 10.4% [13]. The univariate analysis concluded that pre-existing diabetes, resection for malignancy, increased operative time, and concurrent pancreatic abscess or fistula were independent risk factors [13]. CL was shown to be associated with increased length of stay but was not associated with further morbidity or mortality [13].

Oesophageo-gastric surgery

**Oesophago-gastrectomy/gastrectomy:**

CL is an uncommon complication following oesophagectomy [12]. It results from injury to the thoracic duct, the right lymph duct, or other major lymphatics. CL following oesophago gastric abdominal surgery is less well described. Incidence following gastrectomy has been reported as low as 2.0% [9] and as high as 4.17% [21]. Lu et al., found the total number of resected lymph nodes, number of involved lymph nodes, and tumour N-stage as independent risk factors for CL (P<0.05) [21].

Bariatric and anti-reflux surgery:

Chyle leak is extremely rare following bariatric surgery as bariatric operations seldom disrupt the retroperitoneal lymphatics; there are no high-quality studies which aim to determine the incidence, risk factors, or effect on outcomes. Imam et al. report two cases where patients developed CA following Roux-en-Y gastric bypass [22]. A comprehensive literature search only provided a handful of additional cases [23,24]. All cases were associated with an internal hernia, which resulted in lymphatic vessel engorgement and lymphatic extravasation. All were treated successfully with reduction of the hernia and closure of the mesenteric defect [22]. CA is a very rare complication following both laparoscopic and open Nissen fundoplication. Several cases have been described in the literature, but no large studies have estimated incidence or risk factors [25-27].
Colorectal resection surgery

Chyle leak incidence following resection for colon cancer varies between 1.47% [28] and 7.7% [29]. Sun et al. demonstrated that right hemicolectomy (13.3%) is significantly higher risk than left hemicolectomy (4.4%) [29]. Univariate analysis revealed tumour size (P<0.05), tumour location (P<0.01), and number of harvested lymph nodes (P<0.01) as risk factors [29]. However, on multivariate analysis, only tumour location and a number of lymph nodes harvested were shown to be independent risk factors (P<0.05) [29]. Lu et al. also demonstrated that right hemicolectomy is higher risk than left hemicolectomy (P<0.05) and found no significant difference between laparoscopic and open approaches (P>0.05) [21]. Baek et al. identified increased age, the experience of the operating surgeon, and tumour location as risk factors [30]. Lee et al., who studied almost 3000 patients who underwent resection for colon cancer, found CL did not have a significant impact on the length of hospital stay, 3-year, or 5-year survival [31].

CA following resection for rectal cancer is very rare; Lu et al. report an incidence of 2.8% [5]. To our knowledge, no other large studies specifically look at CL post-resection for rectal cancer, although there are several documented case reports [32].

Urological surgery

The retroperitoneal lymphatic glands drain the kidneys and gonads and are the secondary drainage site for the external genitalia, perineum and pelvic organs. As such, retroperitoneal lymphadenectomy in urological surgery may result in the disruption of the major retroperitoneal lymphatic channels [3]. Radical nephrectomy, suprarenal surgery, and retroperitoneal dissection all result in significant lymphatic disruption.

Nephrectomy:

The incidence of CL following nephrectomy is on the rise; some authors have argued that this is due to a rise in the number of centres performing the procedure laparoscopically [33]. Kim et al. report an incidence of 5.1%; incidence was higher in those who underwent lymphadenectomy and in those who underwent left-sided surgery [33]. The authors recommend meticulous clipping of all perihilar and retroperitoneal fibrous fatty tissue during major vessel dissection. They conclude that this is even more important during left-sided surgery and extensive lymphadenectomy. In contrast, Jairath et al. report an incidence of just 0.77% post laparoscopic nephrectomy [34]. Again, left-sided surgery was shown to be a risk factor, yet the authors report a higher incidence in those who underwent simple nephrectomy rather than radical nephrectomy [34]. CA following open nephrectomy is rare, and only a handful of cases have been reported [35].

Retroperitoneal lymph node dissection (RPLND) and pelvic lymph node dissection (PLND) for urological cancers:

The incidence of CL following RPLND varies between 1.5% [36] and 7.6% [37]. Pre-operative chemotherapy and increased intraoperative blood loss have been shown to increase risk [37]. CA is rare following the surgical management of prostate cancer; no large studies have been carried out, and hence incidence has not been accurately estimated. Castillo et al. report a series of five patients who experienced CA following PLND for urological cancer [38]. Four patients were male and underwent robotic prostatectomy and PLND for prostate cancer. One patient was a female who underwent robotic anterior exenteration and extended PLND for infiltrating bladder cancer. In each case, treatment was individualised.

Renal transplant surgery:

Chyle leak following donor nephrectomy is rare; Ng et al. report an incidence of 2.25% following laparoscopic living donor nephrectomy [39] and Harkar et al. report an incidence of 0.29% following open living donor nephrectomy [40]. The authors of both studies argue that incidence can be reduced by meticulous clipping/ligation of all lymph channels adjacent to the renal vessels [39,40]. Crome et al. describe the case of a patient who developed CA post-hand-assisted donor nephrectomy; five litres of chylous fluid were aspirated from the abdomen, and the patient avoided re-operation [41]. Postoperative CA in renal transplants recipients is vanishingly rare; a review of the literature revealed just two cases [42,43].

Nephroblastoma:

Nephroblastoma, or Wilms’ tumour, is a rare form of kidney cancer which typically affects children in their preschool years. Multiple case reports describe CA as a complication of surgical treatment for nephroblastoma. Weiser et al. identified nine cases of children who developed CA following surgical management of nephroblastoma [44]. Left nephrectomy was performed in five cases, right nephrectomy was performed in three cases, and left nephrectomy and partial right nephrectomy was performed in one case. All patients had undergone some form of lymph node dissection; five patients had hilar and PA dissection and four of these underwent additional suprahilar lymph node dissection. Three patients underwent sampling from the hilar, PA and suprahilar lymph nodes. The authors conclude that extensive lymph node dissection, particularly above the level of the renal hilum, appears to be associated with the development of CA. They recommend that formal lymphadenectomy should be performed only where indicated and advocate meticulous ligation of lymphatics [44]. To our knowledge, there are no large studies which describe the incidence of CL following surgery for nephroblastoma or effect on the outcome.

Gynaecological resection surgery

The reported incidence of CL following gynaecological resections varies considerably between studies. Solmaz et al. reviewed 399 patients and reported that 9.0% of patients who undergo RPLND for gynaecological cancers develop CA [45]. Risk factors identified included surgery for an endometrial primary, prior abdominal radiation therapy, and increased resected PA lymph nodes. In contrast, Han et al. retrospectively reviewed over 4000 patients who underwent pelvic and/or PA lymph node dissection and reported a CL incidence of just 0.17% [46]. Incidence was significantly higher in those who underwent PA lymph node dissection. CA was not shown to have a significant impact on the length of stay or mortality, and all cases were managed successfully with a non-operative approach [46].

Vascular Surgery

Injury to the cisterna chyli during abdominal aortic aneurysm (AAA) repair is not uncommon as extensive retroperitoneal dissection is necessary; the degree of injury is usually not of clinical
Chyle leak usually presents as a milky discharge from a surgical drain or wound. It often presents between day 3 and day 8 postoperatively or following the introduction of normal diet [6]. Rarely, CL can present several months postoperatively [6]. Following gynaecological resections, CA can also present as milky vaginal discharge [45]. Although CL is unpleasant and can complicate wound healing, patients do not commonly complain of other symptoms. If a drain has not been placed intraoperatively or if there is no route for chyle to exit the abdomen, then it may accumulate and result in CA. Those with CA may develop abdominal pain and distention, gain weight, and feel short of breath due to increased abdominal pressure [50,51]. Other non-specific symptoms include anorexia, nausea, malaise, change in bowel habit, peripheral oedema, fever, and night sweats [50]. More severe cases can result in dehydration, electrolyte imbalance, malnutrition, and immunologic deterioration secondary to prolonged protein and lymphocyte loss [52]. Occasionally, the raised intra-abdominal pressure due to CA can result in compression of intra-abdominal structures [53] and, in rare circumstances, an erythematous skin rash can develop [54]. If a patient remains intubated at the time of diagnosis, it may be that increased ventilation pressures or a raised diaphragm on imaging are the first signs of CA [55].

**Treatment**

Optimum management of CL remains debated; particularly following major abdominal surgery. To our knowledge, no consensus guidelines exist. Multiple prior series have demonstrated that most chyle leaks following abdominal operations will resolve within 2-3 weeks of diagnosis following conservative measures alone [4]. Non-operative treatment aims to reduce chyle production and reduce lymphatic flow whilst maintaining nutritional balance. Treatment options which reduce chyle formation include somatostatin, a medium-chain triglyceride (MCT) diet, and total parenteral nutrition (TPN) combined with fasting [56]. The most effective method of nutritional support remains a subject of debate [57]. Indeed, Steven et al., who conducted a systematic review, concluded no significant difference between any dietary methods when the time to complete CA resolution was the outcome measured [57]. Patients with significant abdominal distention may undergo paracentesis for symptom relief, although this is associated with further complications [58]. Several authors have published a large series of patients who have successfully been managed non-operatively [2,59,60]. Most authors argue that invasive therapies are only indicated if initial conservative measures have failed. Indeed, repeat laparotomy has been shown to increase morbidity and mortality [47].

**Octreotide**

Somatostatin, also known as growth hormone inhibiting hormone, is a protein hormone which regulates the endocrine system. Its synthetic analogue, octreotide, can be administered subcutaneously due to its relatively long half-life. Somatostatin is an inhibitory hormone, and some of its key functions include suppressing the release of gastrointestinal hormones and inhibiting the exocrine function of the pancreas [4,61]. The use of octreotide in patients with high output CL has been shown to be highly effective; multiple series have demonstrated that its use can cause the dramatic reduction of chylous drain output within two to five days of commencing treatment [4,62]. To our knowledge, no large study has attempted to quantify the extent to which octreotide reduces chylous output following abdominal surgery. Swanson et al. demonstrated that its use in patients with CL following pancreatoduodenectomy, all patients responded to conservative measures and were managed successfully without a return to theatre (unpublished).

**Signs and symptoms**

Chyle leak usually presents as a milky discharge from a surgical drain or wound. It often presents between day 3 and day 8 postoperatively or following the introduction of normal diet [6]. Rarely, CL can present several months postoperatively [6]. Following gynaecological resections, CA can also present as milky vaginal discharge [45]. Although CL is unpleasant and can complicate wound healing, patients do not commonly complain of other symptoms. If a drain has not been placed intraoperatively or if there is no route for chyle to exit the abdomen, then it may accumulate and result in CA. Those with CA may develop abdominal pain and distention, gain weight, and feel short of breath due to increased abdominal pressure [50,51]. Other non-specific symptoms include anorexia, nausea, malaise, change in bowel habit, peripheral oedema, fever, and night sweats [50]. More severe cases can result in dehydration, electrolyte imbalance, malnutrition, and immunologic deterioration secondary to prolonged protein and lymphocyte loss [52]. Occasionally, the raised intra-abdominal pressure due to CA can result in compression of intra-abdominal structures [53] and, in
non-invasive measures, other benefits to its use include earlier surgical drain removal, reduced time to re-introduction of oral nutrition, and decreased length of hospital stay [2,62]. Octreotide is well-tolerated and has a favourable side effect profile.

**Medium chain triglyceride (MCT) diet**

A diet low in fat will result in fatty acids bypassing the lymphatic system and reduce the production of chyle [55]. A protein-rich, low-fat diet aims to decrease lymphatic flow and facilitate closure of chylous fistulae. Many centres advocate that an MCT diet should be trialled immediately following the diagnosis of CL as, in contrast to placing a patient on total parenteral nutrition, it is non-invasive and not associated with significant complications [2]. Pan et al. demonstrated that placing patients on a low-fat diet supplemented with MCTs was the most cost-effective way of managing CA [2]. Having said this, foods containing MCTs can be less palatable and lead to symptoms such as nausea and bloating due to their high osmolarity, which can result in poor compliance [64]. Following the resolution of CL and removal of the surgical drain, a normal diet should be gradually re-introduced over a two to four-week period.

**Total parenteral nutrition (TPN)**

Total parenteral nutrition allows complete bowel rest and decreases lymph production [65]. It also provides appropriate nutrition and promotes reabsorption of intra-peritoneal fluid [60]. Indeed, some centres use postoperative TPN routinely following pancreatic resection to reduce the risk of complications such as CL [66]. Its use alone or other treatments has been shown to promote the closure of chylous fistulae and result in complete resolution of CA without the need for operative intervention [16]. Several authors argue that patients should be fasted and started on TPN in the first instance following the diagnosis of CL [16]. Numerous studies have successfully treated patients with fasting and TPN without complication and the need for surgical intervention [65].

TPN use requires the insertion of a peripheral or central venous catheter. Whilst serious complications are rare, and they can be life-threatening. These include infection, arrhythmia, venous thromboembolism, vascular injury, haemo/pneumothorax, air embolism, and catheter malposition. TPN use has significant financial implications, and its routine use denies patients the benefits associated with enteral feeding [20]. Furthermore, octreotide has been shown to completely resolve CL following abdominal surgery in a timelier manner [2]. TPN is also associated with cholestasis and mucosal integrity disorders [4].

**Drainage**

If a patient is symptomatic postoperatively, and no drain has been placed, then paracentesis may be useful for diagnostic purposes and symptom relief [4]. Whilst image-guided drainage has been shown to be both safe and effective, drainage itself is uncomfortable for patients and recurrence rates are high [67]. The addition of a sclerosing agent such as doxycycline has been shown to reduce the rate of recurrence [68].

**Operative approach and novel methods for intra-operative identification of leak site**

Surgery can be considered if CL continues despite two or more weeks of conservative therapy, if drainage volumes surpass one litre per day, or if metabolic or immunologic complications are encountered [50,69].

Imaging and minimally invasive approaches

Both ultrasound and CT are useful for identifying free intra-abdominal fluid, but neither can differentiate CA from other forms of ascites. Neither is helpful when attempting to localise the site of a CL or plan further treatment. The imaging modalities that can be used for this purpose are lymphoscintigraphy, magnetic resonance imaging (MRI), and lymphangiography. Lymphoscintigraphy is a nuclear medicine imaging modality which has no significant adverse effects; it can, therefore, be used repeatedly if necessary [70]. Although it cannot be used for treatment purposes, lymphoscintigraphy is useful for the precise location of CL in patients who are due to return to theatre. Despite its advantages, this technique requires specialised equipment and expertise which are not always readily available. Lymphoscintigraphy can also be used to assess the patency of the thoracic duct, select patients for theatre, and assess the effectiveness of prior interventions [71]. Heavily weighted T2 images have been shown to be effective in delineating the thoracic duct [72]. Dynamic MRI imaging with an intranodal injection of MR contrast has been employed to demonstrate the site of injury [72] accurately.

Lymphangiography refers to the use of fluoroscopy along with the injection of radio-opaque contrast into the groin lymph nodes in order to visualise a leak site. Sensitivity for detection of CL is between 64% and 86% [71]. As well as being a useful diagnostic tool, it also has a role in minimally-invasive treatment. Several authors describe the successful treatment of CL with ultra-sound guided intranodal lymphangiography with Lipiodol injection. It is proposed that Lipiodol acts as an embolic agent within the lymphatics and the subsequent inflammatory response seals the leaking channels [73].

Formal embolisation of the thoracic duct following lymphangiographic opacification of the lymphatic system by direct trans-abdominal puncture of the cisterna chyli under fluoroscopy and subsequent microcatheter cannulation of the thoracic duct has been reported to have a high success rate with low morbidity [74]. Embolisation is usually combined with coils and liquid embolic such as n-butyl cyanoacrylate or ethylene-vinyl alcohol copolymer [74]. Success rates as high as 90% have been reported if the cisterna chyli can be adequately opacified and cannulated [74]. However, the technique is challenging, and the overall success rate is in the region of 70% [74]. Transvenous thoracic duct embolisation by retrograde cannulation of the thoracic duct has also been described to treat chylous pleural effusion [75].
We propose the following algorithm to manage patients who experience CL following abdominal surgery (Figure 3). Management of potential CL should begin pre-operatively as the best course is prevention since CL is a challenging complication to manage. If a patient is deemed high-risk, surgery should be planned so that unnecessary dissection is avoided. This is particularly pertinent if dissection is required in the PA or SMA root areas. Intra-operatively, extreme care should be taken when dissection is carried out, and the surgeon should meticulously clip/seal any lymphatic channels that are disrupted. If CL is observed, extreme care should be taken to ligate/suture the leak source. Placement of a surgical drain should be considered as this may be useful for both diagnostic and treatment purposes. Following the diagnosis of CL, the patient should be started on octreotide and commenced on an MCT diet in the first instance. If a drain is in-situ, then it should be left in place. If no drain is in situ, then one should be considered. If there is no reduction in the output and nutritional status is compromised, we advise a discussion with a nutrition team, and the patient should be commenced on TPN. The majority of cases should respond to conservative measures alone. One would expect complete resolution of CL within two weeks. If drain output is less than 50ml in a twenty-four-hour period, then drain removal can be considered, and octreotide therapy/TPN can be ceased. A normal diet can be gradually re-introduced over a two to four-week period.

If there is no improvement within two weeks, if the output exceeds 1L per day or >500ml for five or more days, or if the patient experiences metabolic or immunologic complications, more invasive investigation and/or treatment is necessary. One can consider imaging modalities +/- minimally invasive therapeutic options such as image-guided embolisation techniques. If not available, or if this fails, a pre-operative high-fat meal should be given, and the patient should return to theatre for laparoscopy. Intra-operatively, ICG or methylene blue may aid in localising the site of the leak and/or confirming there is no further leak following ligation/suturing of leaking channels. If the CL site cannot be identified, fibrin glue and/or sclerosing agents can be deployed to the suspected leak sites. If a patient is unfit to return to theatre, then regular paracentesis can be considered for symptomatic relief.

**Conclusions**

Chyle leak is rare following major abdominal surgery, but the incidence is increasing. High-risk operations include those where extensive lymph node dissection in the para-aortic, superior mesenteric artery root and retroperitoneal areas is necessary. Most cases of chyle leak are self-limiting, but a persistent leak can result in increased length of stay, malnutrition, and an immunocompromised state. The majority of patients with CL require insertion of a drain, octreotide, and nutritional support only. While the optimum method of providing nutrition remains a source of debate, a low-fat medium-chain triglyceride-based diet is preferable over total parental nutrition. Patients who fail conservative measures should be considered for imaging modalities +/- embolisation techniques. Laparoscopy, which is preferable to laparotomy, should be kept as a last resort. Further studies are required to identify risk factors, assess outcomes, and inform management.

**Declaration of conflicting interests**

Thomas B Russell, Andrei Tanase and Somaiah Aroori declare that there is no conflict of interest.

**Author’s contribution statement**

SA came up with the idea to produce this piece of work. TR carried out the literature search and data analysis. TR drafted the manuscript. AT and SA edited the manuscript. TR carried out the administrative tasks for the project.

**Acknowledgements**

We would like to thank Dr Richard Miles, Consultant Interventional Radiologist*, for providing the image for Figure 2 and for contributing towards the imaging section.

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**Proposed management algorithm**

<table>
<thead>
<tr>
<th>Pre-op</th>
<th>Intra-op</th>
<th>Post-op</th>
<th>Initial management</th>
<th>Improvement</th>
<th>Consider:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify high-risk patients</td>
<td>Minimise unnecessary dissection (especially retroperitoneal)</td>
<td>Drain inserted ± send fluid for analysis</td>
<td>Label drain-in-situ/consider CT &amp;/or paracentesis</td>
<td>Consider gradated introduction of normal diet</td>
<td>Imaging: Discourage octreotide/interventional radiology and/or minimally invasive approaches</td>
</tr>
<tr>
<td>Consider drain placement (especially if there is concern regarding chyle leak)</td>
<td>Ligation, ICG or methylene blue injection was used intra-operatively to successfully identify the leaking site, ligated [76]. If a leak cannot be located intra-operatively, blind application of fibrin glue and sclerosing agents over the presumed leak site are effective treatment modalities [2,58].</td>
<td>Consider grading introduction of normal diet</td>
<td>Consider re-ligation and starting TPN if no improvement</td>
<td>Consider high-fat meal</td>
<td>Consider a return to theatre: Peri-operative high-fat diet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or fluoroscopically guided fibrin glue and/or sclerosing agents may be of benefit</td>
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<td>or if this fails, a pre-operative high-fat meal should be given, and the patient should return to theatre for laparoscopy.</td>
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<td>Intra-operatively, ICG or methylene blue may aid in localising the site of the leak and/or confirming there is no further leak following ligation/suturing of leaking channels. If the CL site cannot be identified, fibrin glue and/or sclerosing agents can be deployed to the suspected leak sites. If a patient is unfit to return to theatre, then regular paracentesis can be considered for symptomatic relief.</td>
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</table>

**Figure 3** Proposed algorithm for the prevention, diagnosis, and initial management of chyle leak following abdominal surgery.
References


