Clip as Nidus for Choledocholithiasis after Cholecystectomy—Literature Review

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ABSTRACT

Background and Objectives: Foreign material in the biliary tree may serve as a nidus for stone formation and would usually present as choledocholithiasis with jaundice or cholangitis. Overall it is a rare occurrence, but there are many anecdotal reports of ingested matter or surgical material such as suture or clips causing biliary stones. Especially interesting are the cases in which there is migration of a metallic clip used in laparoscopic cholecystectomy. Cholecystectomy is such a common operation that although the phenomenon is rare, it is important because it is preventable, and as such a review of the topic seems worthwhile.

Methods: The available literature was searched using the EMBASE and Ovid databases and reviewed. The various devices and sutures used to occlude the cystic duct in laparoscopic cholecystectomy are discussed with reference to their safety.

Results and Conclusion: We found that the harmonic scalpel is a reasonable alternative with minimal complications but is however limited by cost. Electrosurgical vessel-sealing, ultrasonic shears, absorbable sutures such as endoloops (PDS), and polymer clips as well absorbable magnesium-calcium-zinc alloy clip are discussed.

Key Words: clip migration, laparoscopic cholecystectomy, biliary surgery, surgical clip, electrosurgical vessel-sealing devices, ligasure, ultrasonic coagulating shears, harmonic scalpel, absorbable clips

INTRODUCTION

Laparoscopic cholecystectomy (LC) for gallstones is a common procedure with a low rate of complications. It superseded open surgery about 30 years ago because it was obviously superior despite initial concerns about a higher rate of bile duct injury. LC involves identifying and clipping the cystic artery and duct before dividing these structures to excise the gallbladder. Usually a metallic or polymer clip is used to ligate the cystic duct because it is easier than suture ligation. In the traditional open approach, these structures were usually ligated with absorbable sutures. In the days before clips, some surgeons (and old textbooks) cautioned against the use of nonabsorbable sutures such as silk, anywhere within Calot's triangle.

Choledocholithiasis due to a metallic clip used during LC is rare as when it occurs it should be easily recognizable because the imaging will be diagnostic (Figure 1). The pathophysiology is unknown, but ischemia and chronic inflammation with erosion are postulated. Two cases are shown to illustrate the phenomenon (Figures 2, 3, and 4) and a literature review is presented. In addition, a literature review of alternatives to nonabsorbable clips for the cystic duct is used as the basis for a discussion on this topic.

Methods and Results

The available literature was searched using the EMBASE and Ovid databases and reviewed. A search strategy was developed to identify further incidences of clip choledocholithiasis.

The terms clip, choledocholithiasis, and cholecystectomy were applied across the databases of EMBASE and Ovid. The search terms were combined using the AND function. The search yielded 95 results. Duplicates were removed to yield 67 records. Twenty-four records were unrelated to complications postcholecystectomy and removed, leaving 42 records. Two nonenglish reports were removed because no abstracts or full-text translations were readily available. Twenty-one publications were identified from reviewing the references of the initial 40 publications and Google Scholar. Attempts were made to retrieve the full text of all relevant
publications. In circumstances in which full articles were not available, only abstracts written in English were reviewed and excluded if inadequate details were provided. A summary of these results can be seen in Table 1.

A literature search was also undertaken to explore the possible alternatives to ligate the cystic duct, namely absorbable materials and electrosurgical clipless alternatives. The terms cholecystectomy, clip, and absorbable were chosen to identify absorbable materials as suitable alternatives to titanium clips. The AND function was applied to yield 68 results. Duplicates were removed to yield 49 records. Seventeen articles were of no relation, four were not of the English language, six articles were case reports, and two had inadequate details within abstracts. These articles were excluded, yielding a total of 20 articles.

The terms cholecystectomy and ligasure with the AND function yielded 94 articles. Twenty-one duplicates removed. Sixty of those records were removed because they were related to gastric resection, splenectomies, hepatectomies, and hysterectomies. Two publications were in a foreign language and one had insufficient details even within abstract. This yielded a total number of 10 articles.

The terms cholecystectomy AND electrosurgical yielded 96 results. Thirty-two were duplicates. Fifty-nine were unrelated to cholecystectomies or pertaining gallbladder bed dissection but not ligation of the cystic duct. Two of the remaining articles were in a foreign language with inadequate details on abstract, yielding a total of three articles. A summary of this search can be seen in Table 2.

DISCUSSION

Two cases of clip induced choledocholithiasis diagnosed and treated by the authors were the basis for this review (Figures 1–4). The literature shows that nonabsorbable clips used during biliary surgery can migrate and cause various complications. If the clips enter the common bile duct,\(^1\) it could cause choledocholithiasis,\(^2–31\) leading to cholangitis.\(^32–48\) If the clip embeds itself into the duodenal wall, it could cause duodenal ulceration.\(^49–52\) Clips may cause complications such as Mirizzi syndrome postcholecystectomy\(^53\) or even rarely result in choledochoduodenal fistula.\(^55,54\) The time frame of these complications have been reported between 2 weeks and up to 35 y after postcholecystectomy.

Various foreign materials have been reported as the nidus of a gallstone including clips or sutures used during an operation or ingested material such as vegetable or plant matter. Ingested material can more easily enter the biliary system in which there has been surgery such as biliary enteric anastomosis or sphincterotomy; however, it has
been shown to occur even in patients who have not had prior intervention.\textsuperscript{55}

Various suture materials, both absorbable and nonabsorbable used during biliary surgery, have been reported as the nidus for choledocholithiasis.\textsuperscript{56,57} During a choledochotomy, stones can form on the suture used to close the duct.\textsuperscript{58} With modern suture materials, this is likely to be less common.

Inadvertent entry of a clip into the common bile duct for example during bile duct exploration is obviously a different scenario to the more important complication of a cystic duct clip migrating into the bile duct. The pathophysiology of how a clip migrates into the bile duct is unknown. Chong et al.\textsuperscript{55} postulated localized inflammation, ischemia, and necrosis with subsequent migration.

A case report by Ahn et al.\textsuperscript{59} describes a patient who presented three times for choledocholithiasis, and on the initial cholangiogram was found to have two presumed extraluminal clips near the common hepatic duct. On the third presentation, choledochoscopy was performed and found the two metallic clips ulcerating into common hepatic duct wall. This suggests erosion of the clips over time, possibly as a result of foreign body reaction or, as the report describes, serial maceration theory. This hypothesis is further reinforced the case report of Schreuder\textsuperscript{60}, describing a coil of the right hepatic artery migrating to the common bile duct causing choledocholithiasis.

Pang et al.\textsuperscript{61} presented a case series of six cases over a 10-year period with choledocholithiasis because of a Weck Hem-o-lok polymer locking ligation system clip at its core. These patients had undergone bile duct explora-
| Author          | Year  | Complication Type | Core Type       | Postoperative Time | Age | Sex | Indication            | Clinical Course   | CBD Explored? |
|-----------------|-------|-------------------|-----------------|--------------------|-----|-----|-----------------------|-------------------|--------------|
| Ahn et al.      | 2005  | Choledocholithiasis| Clip-metal      | 1 year             | 56  | F   | Cholelithiasis         | Three presentations: first presentation failed ERCP and required PTC, extracted stones and found two clips likely extraluminal to common hepatic duct; third presentation performed choledochoscope, found clips penetrated common hepatic duct. | Not specified    |
| AlSamman et al. | 2019  | Choledocholithiasis| Clip-metal      | 5 years            | 84  | M   | Not specified          | Not specified     | Not specified |
| Angel et al.    | 2004  | Choledocholithiasis| Clip-metal      | 7 months           | 52  | F   | Acute cholecystitis    | Not specified     | Not specified |
| Artifon and Mestieri | 2016 | Choledocholithiasis| Clip-unknown type| 18 months          | 50  | F   | Not specified          | Not specified     | Yes          |
| Attwell and Hawes | 2007 | Choledocholithiasis| Clip-metal      | 6 years            | 57  | M   | Acute cholecystitis    | Large common hepatic duct perforation, requiring biliary stent; very turbulent postoperative period, with 10 ERCPs over 6 years and no evidence of clip stones identified. | Yes            |
| Battat et al.   | 2016  | Choledocholithiasis| Clip-metal      | 12 years           | 54  | F   | Biliary pancreatitis   | Not specified     | Not specified |
| Chen et al.     | 2018  | Migration–duodenum | Clip-metal      | 3 years            | 56  | F   | Chronic cholecystitis  | Not specified     | Not specified |
| Chong and Chong | 2010  | Various            | Mostly metal clips except two cases of absorbable clips | 11 days to 20 years | 31–88 | Various | Various | Various | Not specified |
| Chong et al.    | 2004  | Choledocholithiasis| Clip-metal      | 4 years            | 58  | M   | Not specified          | Uncomplicated; three clips used at LC, one migrated | No            |
| Cookson et al.  | 2015  | Choledocholithiasis| Clip-metal      | 3 years            | 54  | F   | Cholelithiasis         | Not specified     | Not specified |
| Ghavidel        | 2015  | Choledocholithiasis| Clip-metal      | 10 years           | 55  | F   | Not specified          | Uncomplicated     | No           |
| Goncharz et al. | 2010  | Choledocholithiasis| Clip-metal      | 2 months           | 44  | F   | Cholelithiasis         | Subhepatic collection percutaneously drained | Not specified |
| Gonzalez et al. | 2011  | Choledocholithiasis| Clip-metal      | 10 years           | 54  | F   | Not specified          | Not specified     | Not specified |
| Hai et al.      | 2003  | Choledocholithiasis| Clip-unknown type| 6 years            | 57  | M   | Not specified          | Not specified     | Not specified |
| Herline et al.  | 1998  | Choledocholithiasis| Clip-metal      | 20 years           | 78  | F   | Cholelithiasis         | Not specified     | Not specified |
| Hong et al.     | 2014  | Choledochoduodenal fistula | Clip-metal | 10 years        | 48  | F   | Not specified        | Uneventful         | No            |
| Author          | Year  | Complication Type | Core Type             | Postoperative Time | Age | Sex | Indication                        | Clinical Course                                                                 | CBD Explored |
|-----------------|-------|-------------------|-----------------------|--------------------|-----|-----|-----------------------------------|---------------------------------------------------------------------------------|--------------|
| Hussameddin et al. | 2018  | Choledocholithiasis | Clip-metal            | 16 years           | 70  | M   | Cholelithiasis                   | Uneventful                                                      | No           |
| Kager and Ponsioen | 2009  | Choledocholithiasis | Clip-metal            | 4 years            | 65  | F   | Cholelithiasis                   | Subhepatic abscess, second laparotomy                                        | Not specified|
| Karanth et al.  | 2010  | Choledocholithiasis | Clip-metal            | 1 year             | 41  | F   | Not specified                     | Not specified                                                | Not specified|
| Kelly and Hugh  | 1993  | Choledocholithiasis | Cherry stalk          | NA                 | 47  | M   | Cholecystitis                     | Filling defect found on operative cholangiography requiring choledochotomy    | Yes          |
| Khanna and Vij  | 2005  | Choledocholithiasis | Clip-metal            | 5 years            | Mid | F   | Gallstone disease                | Not specified                                                      | Not specified|
| Kim et al.      | 2019  | Choledocholithiasis | Clip-metal            | 14 years           | 74  | F   | Not specified                     | Not specified                                                      | Not specified|
| Kim et al.      | 2007  | Choledocholithiasis | Prolene               | 15 years           | 74  | M   | Calculous cholecystitis           | Open cholecystectomy, found CBD stone requiring choledochotomy to distal CBD, repaired with prolene plus T-tube | Yes          |
| Kou et al.      | 2019  | Choledocholithiasis | Clip–Hem-o-lok        | 3 years            | 84  | M   | Choledocholithiasis              | CBD stone, failed choledochoscope plus ERCP, then converted laparotomy plus T-tube, then repeat ERCP | Yes          |
| Kurella and Maple | 2011  | Choledocholithiasis | clip-unknown type     | 28 years           | 48  | M   | Cholecystitis                     | Not specified                                                      | Not specified|
| Lee et al.      | 2003  | Choledocholithiasis | Clip-metal            | 14 months          | 50  | M   | Cholecystitis                     | Not specified                                                      | Not specified|
| Liu et al.      | 2012  | Migration–CBD      | Clip-metal            | 2–3 months         | 35–76 | M, 2 F | Not specified                     | Clips found in T-tube, choledochoscope found rough and inflammed CBD wall    | Some         |
| Maeda et al.    | 2012  | NA                 | Nylon                 | NA                 | 75  | M   | NA                                | History of gastric cancer underwent distal gastrectomy                    | NA           |
| McMahon et al.  | 2010  | Choledocholithiasis | Clip-metal            | 8 years            | 32  | F   | Cholelithiasis                   | Short, wide cystic duct, complicated with iatrogenic stricture of CBD       | No           |
| Menichella et al. | 2012  | Choledocholithiasis, bilioduodenal fistula | Clip-metal, catgut | 10 years           | 77  | F   | Not specified                     | Not specified                                                      | Yes          |
| Mills et al.    | 2015  | Migration–CBD      | Clip-metal            | 3 years            | 61  | F   | Not specified                     | Not specified                                                      | Not specified|
| Munoz et al.    | 2010  | Choledocholithiasis | Clip-metal            | 30 years           | 57  | F   | Not specified                     | Not specified                                                      | Not specified|
| Nagomi et al.   | 2016  | Mirrizi syndrome   | Clip-polymeric        | Immediate          | 62  | F   | Cholecystitis                     | NA                                                              | No           |
| Obama et al.    | 2000  | Choledocholithiasis | Clip-metal            | 5 years            | 53  | F   | Not specified                     | Not specified                                                      | Not specified|

**Table 1.**
Continued
| Author          | Year | Complication Type       | Core Type            | Postoperative Time | Age | Sex | Indication                        | Clinical Course                  | CBD Explored? |
|-----------------|------|-------------------------|----------------------|--------------------|-----|-----|-----------------------------------|----------------------------------|---------------|
| Oh et al.       | 2003 | Choledocholithiasis      | Clip-metal           | 10 years           | 48  | M   | Not specified                     | Not specified                    | Not specified |
| Olson and Dries | 2015 | Choledocholithiasis      | Clip-metal           | 4 years            | 54  | F   | Cholecystitis                     | Not specified                    | Not specified |
| Paglia and Kew  | 2017 | Migration–CBD           | Clip-metal           | 17 years           | 81  | M   | Not specified                     | Not specified                    | Not specified |
| Panda et al.    | 2012 | Migration–duodenum      | Clip-metal           | 4 months           | 54  | M   | Chronic calculous cholecystitis   | Not specified                    | Not specified |
| Pang et al.     | 2019 | Choledocholithiasis      | Clip–Hem-o-lok       | 4 months           | 31  | F   | Choledocholithiasis               | CBD 12 mm                       | Yes           |
|                 |      |                         | Clip–Hem-o-lok       | 5 months           | 60  | F   | Choledocholithiasis               | CBD 11 mm                       | Yes           |
|                 |      |                         | Clip–Hem-o-lok       | 6 months           | 83  | F   | Choledocholithiasis               | CBD 10 mm                       | Yes           |
|                 |      |                         | Clip–unknown type    | Not specified      | 61  | F   | Chronic cholecystitis             | CBD 11 mm                       | Not specified |
|                 |      |                         | Clip–Hem-o-lok       | 1.5 years          | 72  | F   | Choledocholithiasis               | CBD 13 mm                       | Yes           |
| Peters et al.   | 2017 | Choledocholithiasis      | Clip-metal           | 33 years           | 57  | F   | Not specified                     | Not specified                    | Not specified |
| Petersen        | 2002 | Choledocholithiasis      | Clip-metal           | 14 years           | 79  | F   | Cholecystitis                     | Open cholecystectomy, no complications specified | Not specified |
| Photi et al.    | 2014 | Migration–CBD           | Clip-metal           | 9 years            | 42  | M   | Not specified                     | Not specified                    | Not specified |
| Rajendra et al. | 2009 | Choledocholithiasis      | Clip-metal           | 14 years           | 41  | F   | Not specified                     | Not specified                    | Not specified |
| Rasool et al.   | 2017 | Migration–CBD           | Clip-metal           | 3 weeks            | 37  | M   | Calculous cholecystitis           | Uneventful                      | No            |
| Rawal           | 2017 | Choledocholithiasis      | Clip-metal           | 4 months           | 38  | F   | Acute cholecystitis               | Not specified                    | Not specified |
| Ray and         | 2013 | Choledocholithiasis      | Clip-metal           | 6 years            | 62  | M   | Acute calculous cholecystitis     | Difficult Calot's dissection, wide edematous cystic duct, used ligaclip 400, developed biliary fistula which healed 14 d with conservative treatment | No            |
| Bhattacharya    |      |                         |                      |                    |     |     |                                   |                                  |               |
| Salmon          | 1992 | Choledocholithiasis      | Chromic catgut       | 12 years           | 81  | M   | Not specified                     | Bile leak requiring second operation | Not specified |
| Samim and       | 2008 | Migration – duodenum     | Clip-metal           | 15 years           | 70  | F   | Not specified                     | Not specified                    | Not specified |
| Armstrong       |      |                         |                      |                    |     |     |                                   |                                  |               |
| Schreuder       | 2019 | Choledocholithiasis      | Clip-metal           | 6 years            | 66  | F   | Cholecystolithias                 | Transient postoperative cholestasis | Not specified |
|                 |      |                         |                      | 4 years            | 63  | M   | Not specified                     | Bile duct injury, intraabdominal abscess | Yes           |
|                 |      |                         |                      | 17 years           | 50  | M   | Choledocholithiasis               | Uneventful                      | Not specified |
|                 |      |                         |                      | 5 years            | 48  | F   | Cholecystolithias                 | Complete transaction of CBD, biloma, pseudoaneurysm of right hepatic artery (coiled) | Yes           |
tion in addition to cholecystectomy and had a wide common bile duct of over 10 mm prior to operation. Bile duct exploration and wide cystic ducts are likely risk factors for clip migration.

Despite numerous advances in laparoscopic surgery, the method of occluding the cystic duct with nonabsorbable clips has not changed since the inception of LC. Failure to secure the cystic duct will result in bile leakage and peritonitis. The safety and efficacy of simply clipping the cystic duct with metallic clips has stood the test of time, and there is no driver to change practice. Alternatives to ligation of the cystic duct include electrosurgical vessel-sealing devices such as LigaSure or ultrasonic shears such as the harmonic scalpel.

There have been clinical studies to show that LigaSure is a plausible alternative as shown by Turial et al., Downes et al., and Schulze et al. This has also been supported in a rat model by Marte et al. However, animal studies by Matthews et al. and Shamiyeh et al. have showed that electrosurgical vessel-sealing devices have low bursting pressures, resulting in high rate of failure. In the absence of real evidence of its safety, electrosurgical vessel-sealing devices for the cystic duct cannot be recommended.

There are data on the safety of the harmonic scalpel for sealing the cystic duct. Abdallah et al. demonstrated in an ex vivo model that cystic duct bursting pressures were superior in the harmonic scalpel group compared with the other patient groups utilizing Ligaclicks and LigaSure. This study was further evidence that electrosurgical vessel-sealing devices such as LigaSure can reproduce low cystic duct bursting pressures of an average of 219.7 mm Hg compared with 358 mm Hg in the harmonic scalpel group.

There are data that the harmonic scalpel is superior to conventional diathermy in performing an LC. The in vivo study by Zanghi et al. concluded that it significantly reduced operative time, intraoperative blood loss, and rates of gallbladder perforation. If the harmonic is used for dissection, then its use on the cystic duct and artery would be logical. The absence of clips in Calot’s triangle could only be a good thing and would preclude the possibility of clip induced cholelithiasis. After analyzing all direct and indirect costs, more hospitals might adopt the harmonic scalpel as a more cost-effective alternative overall.

Absorbable materials have been commonly considered to be an alternative for cystic duct ligation. Numerous studies
### Table 2.
Summary of Studies Reviewed Investigating Alternatives to Ligating the Cystic Duct

| Author(s)          | Year   | Study Type                  | Animal/Human | In/ex vivo | Sample Size | Comparison                        | Follow-up | Conclusion                                       |
|--------------------|--------|-----------------------------|--------------|------------|-------------|-----------------------------------|-----------|--------------------------------------------------|
| Abdallah et al.    | 2015   | Prospective randomised      | Human        | Ex         | 458         | Ligaclip vs LS vs HS              | None      | HS has good sealing pressure                     |
| Bali               | 2018   | Prospective randomised      | Human        | In         | 160         | Silk vs titanium clips            | 2 weeks   | Equal complications, silk more cost-effective, clips more time effective |
| Bencini et al.     | 2003   | Retrospective cohort        | Human        | In         | 690         | Absorbable vs titanium clips      | Unsure    | Equal                                            |
| Darzi et al.       | 1997   | Prospective                 | Human        | In         | 415         | Absorbable laproclip vs titanium  | 3 months  | Equal                                            |
| Downes et al.      | 2015   | Prospective                 | Human        | In         | 28          | LS only                           | 6 weeks   | LS can be used to seal cystic duct               |
| Feroci et al.      | 2011   | Retrospective cohort        | Human        | In         | 664         | Absorbable clip only              | Unsure    | Adequate alternative                              |
| Hawasli            | 1994   | Prospective randomised      | Human        | In         | 50          | Absorbable vs metal clips         | 3 months  | Equally effective                                 |
| Klein et al.       | 1994   | NA                          | Animal       | In         | 30          | Absorbable vs metal clips         | None      | Equally effective, absorbable clips require more force to dislodge |
| Leung et al.       | 1996   | Prospective                 | Human        | In         | 227         | PDS clip only                     | 1 year    | Effective                                        |
| Marane et al.      | 2000   | Not specified               | Human        | In         | 170         | Poligleatin vs endoclip           | Unsure    | Suture cost-effective, safe                      |
| Marte and Pintozzi | 2015   | NA                          | Animal       | In         | 30          | LS vs electrosurg                 | None      | LS can be used to seal cystic duct               |
| Matthews et al.    | 2001   | Prospective                 | Human        | Ex         | 64          | LS vs HS vs metal clip            | None      | Metal clip > LS > HS                              |
| Matthews et al.    | 2001   | Prospective                 | Animal       | In         | 9           | LS vs HS vs metal clip            | None      | HS or LS should not be used                       |
| Park and Lee       | 2014   | Case series                 | Human        | In         | 21          | Endoloop                          | Unsure    | Feasible option                                  |
| Rohatgi and Widdison | 2006  | Audit                       | Human        | In         | 494         | Absorbable clips vs titanium clips| None      | Absorbable locking clips superior, no migration or slipping |
| Saha               | 2000   | Prospective                 | Human        | In         | 70          | Absorbable suture vs titanium clip| Unsure    | Feasible option                                  |
| Schulze et al.     | 2010   | Prospective                 | Human        | In         | 217         | LS vs titanium clips              | Unsure    | LS safe                                          |

**Note:** Table continues with more studies not shown in this snippet.
| Author                  | Year       | Study Type         | Animal/Human | Sample Size In/ex vivo | Comparison | Follow-up | Conclusion                   |
|------------------------|------------|--------------------|--------------|------------------------|------------|----------|-------------------------------|
| Schulze et al.         | 2002       | Not specified      | Animal       | In 8                   | LS only    | None     | LS safe                       |
| Shab and Mataraji       | 2010       | Prospective        | Human        | In 80                  | Silk only  | 2 weeks  | LS can be used to seal cystic duct |
| Shamiyeh               | 2002       | NA                 | Animal       | In 10                  | LS only    | None     | LS not safe due to high rate of necrosis |
| Shamiyeh et al.        | 2004       | NA                 | Animal       | In 9                   | Silk only  | None     | LS safe                       |
| Singal et al.          | 2018       | Prospective randomised | Human    | In 140                 | Silk vs titanium clips | 2 months | Equally effective             |
| Sundholm Tepper et al. | 2017       | NA                 | Animal       | In 12                  | Absorbable ligature vs hemoclips | None | Equally effective |
| Suo and Xe             | 2013       | Prospective        | Human        | In 1096                | Absorbable thread vs titanium clips/ HS | 2 months | None |
| Tempe et al.           | 2013       | Prospective randomised | Human    | In 73                  | HS vs electrocautery | None | HS good cost |
| Turaj et al.           | 2011       | Prospective        | Human        | In 22                  | LS         | None     | LS safe                       |
| Vangjardom             | 2018       | Prospective randomised | Human    | In 1363                | Hem-o-lok vs titanium clips | 7 months | Equally effective |
| Yang et al.            | 2014       | Retrospective cohort | Human       | In 772                 | Absorbable clip vs titanium | None | Absorbable safer more effective |
| Yao et al.             | 2003       | Retrospective cohort | Human       | In 9                   | Absorbable clip vs titanium | None | Equally effective |
| Yoshida et al.         | 2017       | NA                 | Animal       | In 261                 | Absorbable magnesium clip only | None | Sufficient sealing |
| Zanghui et al.         | 2014       | Retrospective      | Human        | In 362                 | HS vs metal clips | 6 months | HS advantages, duration, perforation, bile leak |

LS, Ligasure; HS, harmonic scalpel.
and reports have been published to show that the absorbable polymeric clip is a feasible alternative. In an animal study by Klein in 1994, a comparison between absorbable polymeric surgical clips and titanium clips showed that polymeric clips required more force to dislodge than titanium, both axially and transversely. In some LCs, this is not a desirable strategy. Numerous authors including Suo et al., Marane et al., and Saha recommend use of absorbable sutures in cystic duct ligation. In low-resource settings, several studies have shown silk to be a suitable alternative. However, even absorbable sutures can be the nidus for biliary stone formation.

Absorbable sutures are an alternative to metallic clips. LigaTie is a promising new sealing device resembling the cable tie, which has been shown to be effective in animal studies. PDS Endoloops are readily available and highly effective but requires the duct to be divided prior to placement. In some LCs, this is not a desirable strategy. Numerous authors including Suo et al., Marane et al., and Saha recommend use of absorbable sutures in cystic duct ligation. In resource settings, several studies have shown silk to be a suitable alternative. However, even absorbable sutures can be the nidus for biliary stone formation.

Yoshida et al. recently reported new clip technology using a magnesium-calcium-zinc alloy, which is almost completely absorbed by 6 months postoperatively. This was a canine study, and there were no postoperative complications or electrolyte abnormalities reported. Absorbable surgical clip alternatives should be able to reduce the rate of clip induced choledocholithiasis but probably cannot preclude it.

CONCLUSION

In conclusion, any foreign material in the biliary tree, whether absorbable or nonabsorbable, can serve as a nidus for stone formation. Absorbable materials may be less likely to cause such a problem. The mechanism by which a cystic duct clip migrates and the factors that make it more likely, are speculative. Options to seal the cystic duct without clips include the harmonic scalpel and Li-gaSure. The harmonic scalpel has proven to be adequate in both animal and human studies but its use is limited by cost.

The routine use of nonabsorbable clips on the cystic duct is safe and effective; however, there will continue to be the rare cases of clip induced choledocholithiasis. This curious phenomenon of clip migration and stone formation after LC is so rare that it is not a reason to recommend a change in practice; however, there are readily available alternatives that may lower the risk. The senior author routinely uses a PDS Endoloops on the cystic duct when the operative conditions easily allow it and especially in young patients. The fact that research is continuing with new methods and new clips in LC shows that surgeons must have an inkling that nonabsorbable clips on biliary structures is not optimum. It will be interesting to see whether in 20 years nonabsorbable clips will still be used on the cystic duct in LC.

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