CLINICAL REVIEW

Iatrogenic splenic injury

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Background: Iatrogenic injury to the spleen is a recognised complication of abdominal surgery but the extent of the problem is often under-estimated. This may be due to failure to report splenic injury on the operation note or inaccurate recording of the indication for splenectomy. In this review article we have tried to estimate the incidence of iatrogenic splenic injury during abdominal surgery, the morbidity and mortality associated with splenic injury and the risk factors for injury to the spleen. We have also identified the common types and mechanisms of injury to the spleen and have made suggestions as to how splenic injury can be avoided and, when it occurs, how it should be managed. Methods: A Medline literature search was performed to identify articles relating to "incidental splenectomy", "iatrogenic splenic injury", "iatrogenic splenectomy" and "splenectomy as a complication of common abdominal procedures". The relevant articles from the reference lists were also obtained. Results: Up to 40% of all splenectomies are performed for iatrogenic injury. The risk of splenic injury is highest during left hemicolectomy (1-8%), open anti-reflux procedures (3-20%), left nephrectomy (4-13%) and during exposure and reconstruction of the proximal abdominal aorta and its branches (21-60%). Splenic injury results in prolonged operating time, increased blood loss and longer hospital stay. It is also associated with a two to ten-fold increase in infection rate and up to a doubling of morbidity rates. Mortality is also reported to be higher in patients undergoing splenectomy for iatrogenic injury. The risk of injury to the spleen is higher in patients who have previously undergone abdominal surgery, in the elderly and in obese patients. A transperitoneal approach significantly increases the risk of splenic injury during left nephrectomy compared with an extraperitoneal approach and the risk is even higher if the indication for surgery is malignancy. Excessive traction, injudicious use of retractors and direct trauma are the commonest mechanisms of injury. Conclusions: The incidence of iatrogenic splenic injury is underestimated because of poor documentation. Splenic injury during abdominal surgery can be reduced by achieving good exposure and adequate visualisation, avoiding undue traction and by early careful division of splenic ligaments and adhesions. When the spleen is injured splenic preservation is desirable and often feasible, but this should not be at the expense of excessive blood loss

Keywords: Iatrogenic splenic injury, spleen, splenectomy

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INTRODUCTION

Iatrogenic injury to the spleen may be defined as any unintentional damage caused to the spleen by the surgeon or the assistant(s) during a surgical procedure. It is a recognised perioperative complication with various abdominal procedures. However, the true extent of the problem is difficult to assess. It is perceived as a failing of the surgeon and is not always recorded in operative notes and operative statistics unless it is followed by a splenectomy. Occasionally, surgeons have even failed to record in the operation note that splenectomy had been performed.[1] In other cases a splenectomy, which was performed for iatrogenic trauma, was listed as having been performed for improved exposure or as part of a radical procedure. Often the details and stated indications for splenectomy are vague.[2-7] Injury to the spleen during an abdominal procedure results in increased operative time and blood loss as the surgeon attempts to repair the damage or perform a splenectomy.[8] Splenectomy itself has been shown to increase morbidity and prolong hospital stay.[8-11] In this review article we have attempted to determine the incidence of iatrogenic splenic injury associated with various abdominal procedures and to identify any risk factors for splenic injury. By examining the types and mechanisms of injury to the spleen we have tried to highlight ways of preventing or reducing the incidence of splenic injury.

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FREQUENCY OF IATROGENIC SPLENIC INJURY

Information on the incidence of splenic injury during abdominal operations can be obtained from studies relating to splenectomy (Table 1). This is unavoidably an underestimate of the true incidence as it does not include splenic injuries treated conservatively. In at least eight of these studies there was no distinction between splenectomy carried out as part of a planned radical procedure and splenectomy performed because of unintended injury to the spleen, and the two groups are simply included under the heading "incidental splenectomy". Often, splenectomy for iatrogenic injury is documented under another indication. In one case of iatrogenic splenic injury during an exploratory laparotomy for a gunshot wound, the splenectomy was recorded as secondary to the

gunshot wound.[1] Similarly, splenectomy for iatrogenic injury is often recorded as being part of a radical cancer procedure or to facilitate exposure in procedures for benign lesions. In spite of these deficiencies, splenectomy for iatrogenic injury accounts for between 9% and 40.4% of all splenectomies performed.[12,13] Unfortunately, in most of these studies there is little or no information as to the total number of abdominal operations performed in the institution during the study period or the type of operations performed. Without this information it is difficult to determine the incidence of splenectomy for iatrogenic injury.

Peck and Jackson (1964) reported on 95 splenectomies performed in two hospitals over four years.[2] Twenty two of these (23%) were for iatrogenic injury. During the same period 4938 abdominal procedures were performed. Splenectomy, therefore, was performed for iatrogenic injury in only 0.44% of cases. Roy and Geller (1974) reported a similar percentage (0.38%) of splenectomies for iatrogenic injuries in their institution.[14] They reported 34 splenectomies for iatrogenic injury in 9000 abdominal procedures. These figures would suggest that iatrogenic injury to the spleen is a rarely encountered problem. This is certainly the case for procedures such as cholecystectomy and appendicectomy. However, in other abdominal operations that involve dissection in the left upper quadrant, iatrogenic injury to the spleen is encountered more often. Upper gastrointestinal procedures, such as gastrectomy, open hiatus hernia repair, fundoplication and vagotomy and drainage, constituted between 9.8% and 53.8% of the procedures which led to iatrogenic splenic injury and subsequent splenectomy.[1,15] Colonic surgery was responsible for between 34.3% and 59.9% of splenectomies for iatrogenic injury.[12,16] Between 3.7% and 20.9% of splenectomies for iatrogenic injury occurred during left nephrectomy.[12,16] Abdominal vascular procedures accounted for another 1.7% to 14.2% of causes.[12,17] These figures vary widely because the case load and type in the reporting institutions is so different. It is clear, however, that colonic, upper gastrointestinal and abdominal vascular procedures, as well as left nephrectomy, are the operations with the highest risk of splenic injury.[1,12,15-19]

Colonic surgery

Splenectomy for iatrogenic splenic injury occurs most often during colonic operations. This is due, in part, to the large number of colonic procedures performed. Splenic injury has been reported to occur in 1.2% to 8% of colonic procedures.[11,24] This is not unexpected in view of the proximity of the splenic flexure of the colon to the spleen itself. In fact, Langevin et al (1984) reporting on 993 colonic procedures found no injuries to the spleen in the 733 procedures not requiring mobilisation of the splenic flexure.[24] On the other hand, there were eight (3.1%) splenic injuries amongst the remaining 260 colonic procedures requiring splenic flexure mobilisation. Of these, only three required splenectomy giving a 1.2% splenectomy rate. This is one of the lowest splenectomy rates reported

Author(s) and References	Year	Total Number of Splenectomies	Number of Splenectomies Secondary to Iatrogenic Trauma	%
Peck and Jackson[2]	1964	95	22	23
Rich et al[1]	1965	925	244	26
Daoud et al[19]	1966	106	24	22.6
Lieberman and Welch[13]	1968	438	176	40.4
Hodam[20]	1970	310	50*	16*
Olsen and Beaudoin[17]	1970	584	121	20.7
McKinnon et al[21]	1973	406	163*	40.1*
Slater[23]	1973	50	17	34
Fabri et al[22]	1974	1944	566*	29*
Roy and Geller[14]	1974	158	34	21
Walstad[10]	1974	71	21	29.5
Cioffiro et al[16]	1976	237	39	16
Danforth and Thorbjarnarson[18]	1976	981	185	18.9
Klaue et al[5]	1979	542	32	5.9
Traetow et al[4]	1980	2417	659*	27.3*
Schwartz et al[7]	1982	193	89*	46.1*
Standage and Goss[15]	1982	277	67	24.2
Fellows et al[6]	1988	3712	1388*	37.4
Coon[12]	1990	1557	134	9
Glass and Gilbert[3]	1996	28	9*	32*

Table 1: Proportion of incidental splenectomy of total splenectomies performed
*Distinction between incidental splenectomy secondary to trauma or part of planned procedure is unclear in these studies

Grade	Haematoma/Laceration/ Vascular Lesion	Description of Injury
1	Haematoma	Subcapsular, nonexpanding, <10% surface area
1	Laceration	Capsular tear, nonbleeding, <1cm parenchymal depth
2	Haematoma	Subcapsular, nonexpanding, 10-50% of suface area, intraparenchymal, nonexpanding <2cm
2	Laceration	Capsular tear, actively bleeding
3	Haematoma	Subcapsular, >50% surface area, or expanding; ruptured subcapsular haematoma with active bleeding
3	Laceration	>3cm deeo or involving trabecular vessels
4	Haematoma	Ruptured intraparenchymal haematoma with active bleeding
4	Laceration	Laceration involving segmental or hilar vessels producing major devascularisation (>25%)
5	Laceration	Completely shattered spleen
5	Vascular	Hilar vascular injury that devascularises the spleen

Table 2: Splenic injury grading (Organ Injury Scaling Committee of the American Association for the Surgery of Trauma[75])

for this type of procedure. Walstad (1974) reported a similar splenectomy rate of 1.3% during 307 left colonic procedures and Danforth and Thorbjarnarson (1976) reported a rate of 1.4% in 2807 colectomies.[10,18] Amongst 350 patients treated surgically for diverticular disease, eight (2.3%) splenectomies were performed for iatrogenic injury.[25] The highest incidence (8%) of splenectomy during left-sided colonic surgery was reported by Konstadoulakis et al (1999); 22 (7.8%) splenectomies were carried out during 281 left hemicolectomies.[11] On the other hand, during 360 sigmoid resections only three (0.83%) splenectomies were performed for iatrogenic trauma.

Upper gastrointestinal surgery

Iatrogenic splenic trauma has been reported with most upper gastrointestinal procedures. The incidence reported varies between 0.9% and 19.6% but appears to be generally higher than that reported for colonic surgery.[9,18] Historically, vagotomy was one of the procedures often associated with injury to the spleen. Klaue et al (1979) and colleagues reported 25 incidental splenectomies for iatrogenic trauma in 702 (3.6%) vagotomies.[5] Walstad (1974) reported a similar incidence (4.1%) in 195 vagotomies, while Peck and Jackson performed 11 (3.7%) splenectomies in 299 vagotomies.[2,10] The incidence of splenectomy reported during gastrectomy ranges from 0.9% to 3.4%.[2,10,12,18] This is somewhat higher for transhiatal oesophagectomy with an incidence of between 3% and 11%.[26,27] However, in a review of 23 articles reporting on a total of 1353 patients undergoing transhiatal oesophagectomy, Katariya et al (1994) could only identify 30 (2.6%) patients requiring splenectomy for surgical trauma.[28]

Splenic injury appears to be very common indeed during open anti-reflux procedures. Except for one report of a 3% incidence of splenectomy during hiatus hernioplasty, splenic injury occurred in 7% to 19.6% of patients undergoing open anti-reflux surgery.[9,12,29] Open bariatric procedures carry a 3% risk of splenic injury.[30]

Left nephrectomy

Iatrogenic splenic injury during left nephrectomy is the third commonest reason for iatrogenic splenectomy although Bozzell and Powell (1954) felt that "injuries to the spleen complicating operations on the left kidney are extremely rare".[31,32] More recent reports have shown that this is certainly not the case. Indeed, the risk of splenic injury during left nephrectomy is significant, with a reported incidence of between 4.3% and 13.2%.[31-34]

Vascular surgery

The commonest vascular intra-abdominal procedure is abdominal aortic aneurysm repair. Splenic injury occurs in 0.1% to 1% of abdominal aortic aneurysm repairs.[12,35] Eaton et al (2000) reported 17 (0.5%) splenectomies in 3350 abdominal vascular procedures performed over 17 years.[35] The risk of

Authors and References	Year	Procedure	Morbidity and Mortality	Morbidity/Mortality with Splenectomy % (n=)	Morbitiy/ Mortality without Splenectomy % (n=)
Walstad[10]	1974	Vagal and gastric	Not specified	84 (11/13)	15 (101/682)
Roy and Geller[14]	1974	Colonic, gastric and left nephrectomy	Wound infection	45 (15/33)	15 (5/33)
Fabri et al[22]	1974	Gastric, colonic and pancreatic	Complications (not specified)	64 (-)	32 (44/136)
			Mortality	28 (-)	5 (7/136)
Polk[29]	1976	Open fundoplication	Wound infection	16 (3/18)	1 (1-98)
Rogers et al[9]	1980	Nissen fundoplication	Mixed (infection, PE*, ileus)	36 (9/25)	12.5 (9/72)
Ferraris and Sube[38]	1981	Open fundoplication	Severe sepsis	20 (2/10)	2 (2/99)
Rodkey and Welch[25]	1984	Diverticular disease	Mortality	37 (3/8)	6 (19/342)
Konstadoulakis et al[11]	1999	Left colonic	All infection	24 (6/25)	0 (0/25)
Eaton et al[35]	2000	Major abdominal vascular	Infection	65 (11/17)	18 (3/17)
			Mortality	18 (3/17)	0 (0/17)

* PE: Pulmonary embolus

Table 3: Morbidity and mortality rates with and without splenectomy

splenic injury was highest for thoracoabdominal aneurysm repair with an incidence of 5% amongst 107 repairs. Left renal artery bypass also carried a 4% risk of splenectomy for splenic injury. The highest risk of splenic injury reported is in patients requiring exposure and reconstruction of the proximal abdominal aorta and its major branches. Medial rotation of the abdominal viscera is one method of achieving exposure of this segment of aorta. A splenic injury risk of 21.3% has been reported in association with transabdominal medial visceral rotation.[36] The risk is even higher (60%) for patients undergoing this procedure as an emergency.[36]

Iatrogenic splenic injury has been reported less frequently with other abdominal procedures such as pancreaticoduodenectomy, drainage of subphrenic abscess, adrenalectomy, incisional hernia repair, cholecystectomy and even inguinal hernia repair.[1,10,17,18,23]

MORBIDITY AND MORTALITY OF IATROGENIC SPLENECTOMY

The sight of blood collecting in the left upper quadrant is often a sign of injury to the spleen. It not only entails prolonging the operation, while attempts are made to repair or remove the spleen, but also results in increased blood loss and higher morbidity and mortality rates.

Konstadoulakis et al (1999) compared a group of patients undergoing colectomy with splenectomy with a similar group undergoing colectomy only.[11] They found that a significantly larger proportion of patients in the splenectomy group had operations that lasted longer than 180 minutes. They found no difference, however, in the proportion requiring a blood transfusion. On the other hand, Eaton et al (2000) in a case-controlled analysis of patients undergoing abdominal vascular surgery found that the operating time was longer for patients undergoing splenectomy for iatrogenic trauma compared with controls, although not significantly so.[35] Mean estimated blood loss, however, was significantly higher in the study group compared with controls and blood transfusion requirements were higher for the splenectomy group, both intra-operatively and post-operatively. Similarly, intra-operative blood loss was found to be much greater in patients undergoing incidental splenectomy with gastrectomy, compared with those not sustaining splenic injury.[40]

Morbidity of splenectomy

Morbidity rates have been shown to be significantly increased in patients requiring splenectomy for iatrogenic splenic injury with various procedures (Table 3). In patients undergoing open anti-reflux procedures, for example, incidental splenectomy for injury increased the severe sepsis rate from 2% to 20%.[38]

In another study on anti-reflux surgery, the infection rate was only 1% but increased to 16% when splenectomy was performed.[5] In a further group of patients undergoing open Nissen fundoplication the risk of various complications increased from 12.5% to 36% when the spleen was injured and removed.[9] Similarly, patients requiring splenectomy during gastrectomy had an infection rate that was four times higher than those patients who did not require a splenectomy.[40] Walstad (1974) also showed that the complication rate after gastric and vagal procedures was 83.8% when splenectomy was performed, in contrast with 14.8% when this was not necessary, although the control group was operated on during a different study period.[10] This trend was confirmed for various gastrointestinal procedures where the morbidity rate was 64% for the splenectomy group compared with 32% in the control group.[22]

In patients undergoing left hemicolectomy for cancer, the complication rate was found to be significantly greater in patients undergoing splenectomy.[11] This was also the case in patients undergoing abdominal vascular surgery, in whom infectious and cardiac complications were both significantly higher in patients who had undergone a splenectomy.[35]

Fujita et al (1996) in a study of patients undergoing total gastrectomy for cancer found that intra-operative blood loss, splenectomy and distal pancreatectomy correlated significantly with the development of postoperative infection.[40] However, on multivariate analysis only operative blood loss greater than 600ml was found to be an independently significant variable associated with the development of infection. Splenectomy was not an independent risk factor for infection following total gastrectomy on multivariate analysis.

Hospital stay

Hospital stay was found to be significantly longer in patients undergoing abdominal vascular surgery and splenectomy, compared with those not sustaining splenic injury.[35] Similarly, the hospital stay was prolonged in patients requiring splenectomy with Nissen fundoplication from 9.4 to 15 days, although this failed to achieve statistical significance.[9] With colonic surgery for cancer, however, additional splenectomy significantly increased the duration of hospital stay.[11]

Mortality of splenectomy

Mortality rates have also been reported to be higher in patients sustaining splenic injury and requiring splenectomy, although whether this is due to the splenectomy per se is difficult to ascertain (Table 3). Amongst patients undergoing surgery for diverticular disease the mortality rate was reported as 5.6%, but this increased to 37.5% when splenectomy was also performed.[25] In the case of total gastrectomy, although the mortality was increased from 2% to 6% when splenectomy for injury was performed, this was not found to be statistically significant.[40] Fabri et al (1974), however, found that the mortality after gastrointestinal surgery was increased from 5% to 28% when splenectomy was performed.[22]

In vitro and *in vivo* studies have shown that splenectomy leads to impaired Kuppfer cell response to an antigenic challenge and to long-term depression of T cell responses.[24,41,42] This raises the concern that splenectomy for iatrogenic injury during abdominal procedures for cancer may lead to a diminished ability for removal of tumour micrometastases and hence an effect on long-term survival.[43-45] The effect of splenectomy on the long term survival of patients with colonic cancer has been studied but the results are controversial. Davis et al (1988) showed that long-term survival in patients with Dukes' C colonic cancer was reduced if splenectomy was performed.[46] On the other hand, Varty et al (1993) and Konstadoulakis et al (1999) showed that splenectomy in patients undergoing surgery for colon cancer did not influence long-term survival.[11,47] A significantly prolonged survival of patients with Dukes' C colonic cancer undergoing colonic surgery and splenectomy has also been reported.[48]

Post-splenectomy sepsis

Another concern of performing splenectomy is the risk of overwhelming post-splenectomy sepsis. Post-splenectomy sepsis was first reported by King and Schumacker (1952), in infants who had undergone a splenectomy.[65] There is evidence that post-splenectomy sepsis is also a risk to healthy asplenic adults and that this is a life-long risk.[49,50] Standage and Goss (1982) reported three (1.7%) cases of pneumococcal post-splenectomy sepsis out of 149 unvaccinated patients who had had a splenectomy during a mean follow-up period of 76.5 months. Schwartz et al (1982) found that the risk of fulminant sepsis was one case per 545 person-years of follow-up and the risk of mortality from the condition was one per 1090 person-years of follow-up.[7] They concluded that although fulminant sepsis after splenectomy was a potential problem, the risk in the general adult population was very low.

RISK FACTORS FOR IATROGENIC SPLENIC INJURY

Previous surgery

Various studies have shown that the risk of splenic injury is significantly higher if the patient has had previous abdominal surgery, particularly in the left upper quadrant. As early as 1969, Devlin et al showed that re-operation on the left upper quadrant was an important factor predisposing the spleen to iatrogenic injury.[37] Ferraris and Sube (1981) encountered only six (6.9%) splenectomies in 87 primary anti-reflux open procedures and four (18.2%) splenectomies in 22 re-operations.[38] Similarly, the risk of splenic injury during bariatric surgical procedures was only 2% for primary procedures but increased more than six-fold to 13% for re-operation.[30] Out of 244 splenectomies for iatrogenic injury reported by Rich et al (1965), 45 (18%) were undertaken in patients who had undergone previous abdominal operations.[1] The increased risk of injury to the spleen with previous surgery is due to the development of dense adhesions in the left upper quadrant of the abdomen.[12] Traction on various structures indirectly causes traction on the splenic capsule, through these

adhesions, resulting in splenic injury. Difficult dissection of these adhesions to obtain exposure and to free structures may also result in direct injury to the spleen.

Type of surgical approach

The type of incision utilised has been reported to have a bearing on the risk of injury to the spleen. Danforth and Thorbjarnarson (1976) found that the most frequently employed incision in operations associated with splenic injury was the midline incision (52.4%).[18] Left rectus and left paramedian incisions were far less commonly utilised in their group of 185 patients requiring splenectomy for iatrogenic injury. They concluded that better access to the left upper quadrant was obtained through the left rectus and left paramedian incisions, compared with the midline incision. However, there is no information in their article as to the frequency with which the different incisions were utilised in the whole group of patients undergoing abdominal procedures during the study period. Similarly Rich et al (1965) found that 74 (34.3%) of their group of 244 patients undergoing splenectomy for iatrogenic injury had a midline incision.[1] They concluded that poor exposure was probably a contributing factor to splenic injury during procedures performed through an upper midline incision. Again there was little evidence in the article to support this claim as the frequency with which the midline incision was used was not specified.

In the case of a left nephrectomy, the risk of splenic injury is much higher with a transperitoneal compared with an extraperitoneal approach. All 18 splenic injuries amongst 418 left nephrectomies reported by Cooper et al (1996) occurred with a transperitoneal approach to the left kidney.[31] Only one report of splenic injury during an extraperitoneal left nephrectomy could be identified in the literature.[39]

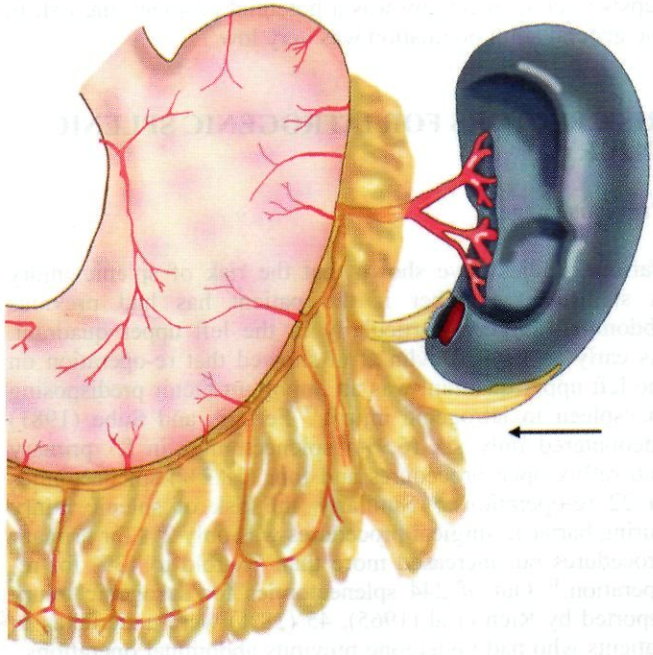

Figure 1: Diagram showing lieno-gastric and lieno-omental bands with splenic capsular tear (arrow indicates direction of traction most likely to cause injury)

Nature of pathology

In the case of a left nephrectomy, splenic injury is more likely if the indication for surgery is malignant disease.[31] Other factors associated with incidental splenectomy during left nephrectomy include the size of the kidney, and the size and location of the lesion itself. In the study by Cooper et al (1996), 9 of 11 malignancies associated with splenic injury involved the superior pole of the kidney or extended outside the kidney.[31] Mejean et al (1993) also identified location of the tumour in the upper part of the kidney as a significant risk factor for splenic injury.[33]

Dense adhesions between the colon and the splenic capsule make splenic injury very much more likely during a left hemicolectomy or extended right hemicolectomy because mobilisation can only be achieved by dividing these adhesions and minimal traction may produce a capsular tear in a friable spleen.[24]

Patient characteristics

Over half the 176 patients sustaining iatrogenic injury to the spleen reported by Lieberman and Welch (1968) were noted to be obese.[13] This may be due to difficulty with achieving adequate exposure but the authors hypothesised that this was due to the fact that parietal reflections are usually of poor quality and non-resilient. In a study of bariatric surgical procedures, however, only 3% of this group of morbidly obese patients sustained splenic injury.[30]

Advancing age is another often-quoted risk factor for splenic injury.[14,16,37] Devlin et al (1981) postulated that increased friability of the spleen secondary to degenerative vascular disease, as well as lack of rib elasticity leading to over vigorous retraction of the left costal margin, accounted for the increased incidence of iatrogenic splenic injury in elderly patients.[37] The mean age of patients undergoing splenectomy for iatrogenic injury was found to be considerably higher than in patients undergoing splenectomy for other indications although this is due in part to the fact that splenectomy for non-iatrogenic trauma and elective indications is often required in younger people.[16] Cooper et al (1996) also found that patients undergoing left nephrectomy (and who sustained a splenic injury) were significantly older than those who did not.[31]

MECHANISMS AND TYPES OF INJURY TO THE SPLEEN

The spleen may be injured in three ways: traction, application of retractors or directly by the surgeon's instruments.

Traction

Traction appears to be the commonest mechanism of injury.[2,9,12,16,17,18,24,31,34,36] Lord and Gourevitch (1965), in

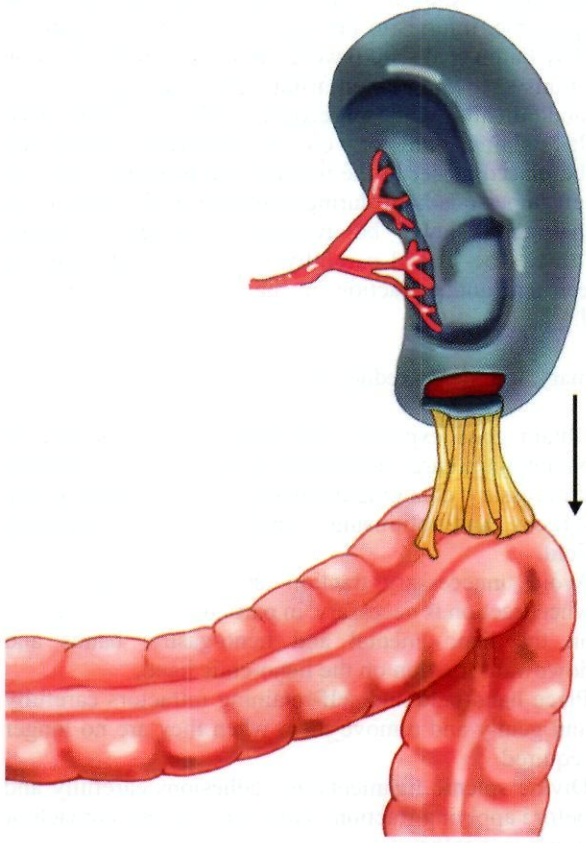

Figure 2. Diagram showing lieno-colonic ligament and a splenic capsular tear (arrow indicates direction of traction most likely to cause injury)

a large series of autopsy specimens, first demonstrated a peritoneal band attaching the greater omentum to the lower pole and hilum of the spleen (Figure 1).[51] They showed how slight medial traction on this ligament during gastrectomy may avulse it from the spleen. Traction on other peritoneal attachments, such as the lienophrenic ligament, the lienogastric ligament and the lienocolic ligament, may also cause splenic injury (Figure 2).[17,18,31] Cioffiro et al (1976) found that 38 out of 39 splenic injuries were caused by traction on the peritoneal or omental attachments of the spleen.[16] Vigorous traction of the stomach downward and to the right during upper gastrointestinal procedures or strong downward traction on the splenic flexure of the colon and its omentum produced the largest number of splenic injuries in their series. Similarly, during left nephrectomy 15 out of 18 splenic injuries reported by Cooper et al (1996) were caused by traction.[31] Olsen and Beaudoin (1970) reported that three quarters of all splenic injuries in their series were caused by traction on the stomach, on the lienocolic ligament during colonic surgery or on the phrenicolienal adhesions during retraction for exposure.[17] Similarly, Peck and Jackson (1964) identified traction as the cause of splenic injury in 15 out of 17 cases.[2]

Retractions

The use of retractors can also cause injury to the spleen, either directly or indirectly through excessive traction on the abdominal wall. Retractors are thought to have been responsible for splenic injury in between 11% (31) to 15% (35) of cases. Peters et al (1990) reported that two out of six splenic injuries during bariatric surgery were caused by the use of a self-retaining retractor.[30]

Direct injury

Direct injury to the spleen by the operating surgeon is reported less frequently. Rogers et al (1980) reported three out of 22 splenic injuries during open Nissen fundoplication to be caused by direct instrumental injury, and Cooper et al (1996) reported only one direct instrumental injury to the spleen out of 18 splenic injuries during left nephrectomy.[9,31]

Types of injuries

Capsular tears, lacerations, avulsions and subcapsular haematomas are the injuries most frequently encountered; capsular tears are the commonest.[1,9,24,30,31,35] The lower pole of the spleen appears to bear the brunt in most cases. Nine out of 18 splenic injuries reported by Cooper et al (1996), seven out of eight reported by Eaton et al (2000), five out of eight reported by Langevin et al (1984) all involved the inferior pole of the spleen.[24,31,35] The hilum, the posterior surface and the upper pole of the spleen are less commonly injured.[31,36] This is not surprising as most injuries are caused by traction on peritoneal attachments to the spleen which have been shown to be concentrated at the lower pole.[52]

PREVENTION OF IATROGENIC SPLENIC INJURIES

The evidence base for making recommendations for avoiding splenic injury is limited. However, there is little doubt that good exposure and adequate visualisation is important in preventing injury to the spleen. Achieving this without undue traction may not be easy. Langevin et al (1984) felt that their low incidence of splenic injury (3.1%) during colorectal surgery was, in part, due to good visualisation.[24] This was achieved by positioning the patients in a modified lithotomy position with the operating surgeon standing between the legs of the patient where visualisation was optimal and another surgeon positioned to the right of the patient. The ultimate in adequate visualisation can be obtained at laparoscopic surgery. Splenic injury during laparoscopic surgery is rare in procedures such as fundoplication, which are associated with a significant splenic injury rate when done conventionally. Indeed, in a prospective randomised study comparing laparoscopic with conventional Nissen fundoplication, there were two patients who underwent splenectomy in the open group but none in the laparoscopic group.[63] In a review of the literature Hinder et al (1997) could only identify two (0.1%) patients who required splenectomy out of 2453 patients undergoing laparoscopic Nissen fundoplication.[64]

In open surgery an adequate incision is an essential factor for good exposure.[16] Carmignani et al (2001), by changing the incision utilised for radical left nephrectomy, managed to reduce the incidence of splenic injury from 13.2% to 2.6%.[34] For the first group a xipho-umbilical-subcostal anterolateral transabdominal approach was used while for the second group a 'Mercedes' cruciate, bilateral subcostal approach with a T-vertical cephalad extension was chosen. The latter incision, together with the use of an abdominal polyretractor and a fixed Rochard subcostal retractor, achieved optimal exposure and visualisation avoiding the need for blind traction. Similarly Mejean et al (1999) felt that an anterior subcostal incision achieved superior exposure to a midline incision for nephrectomy and that this could help decrease the incidence of splenic injury.[33] In the case of a left nephrectomy, using an extraperitoneal approach where possible, was the best way of reducing splenic injury. In a large series of donor nephrectomies using an extraperitoneal approach, no splenectomies were documented.[55-57]

Reducing traction is necessary to limit splenic injuries. When some traction is necessary, such as in the case of splenic flexure mobilisation, great care should be exercised during this manoeuvre and the need for gentle handling of peri-splenic tissues is clear.[2,36,53] Lieberman and Welch (1968) have recommended placing a moist pack above the spleen as the initial step in performing upper gastrointestinal surgery to protect the spleen and relieve tension as the body of the stomach is drawn downward during mobilisation.[13] Olsen and Beaudoin (1970) felt that traction on the stomach downward and to the right caused tension on the lieno-omental ligament resulting in capsular avulsion but traction downward and to the left did not put the ligament on stretch and avoided splenic injury.[17] The use of metal clips to secure the short gastric vessels during upper gastrointestinal surgery may be another way of avoiding undue traction on the stomach.[9]

Others have recommended early and careful division of splenic ligaments and adhesions to avoid splenic injury. As early as 1968, partial mobilisation of the stomach has been recommended prior to vagotomy as a way of reducing the risk of traction injury.[54] Rogers et al (1980) also recommended sharp division of the spleno-peritoneal folds prior to commencing mobilisation of the distal oesophagus and proximal stomach for Nissen fundoplication to avoid splenic injury.[9] Similarly, transection of the lieno-omental peritoneal bands and the lieno-colic ligament promptly after entering the peritoneal cavity has been recommended for left nephrectomy.[12] Hugh et al (1968) showed that by "defusing" the spleen none of 417 patients undergoing abdominal procedures over a five year period required splenectomy.[52] Their operative strategy involved division of the irregular peritoneal attachments to the lower pole of the spleen with diathermy immediately on entering the abdominal cavity. They felt that this technique converted the attachments of the omentum and stomach to the spleen to a linear shape, thus, distributing traction forces more evenly on the splenic capsule. Despite these manoeuvres an unspecified number of minor splenic capsular tears still occurred but were all treated conservatively.

Obtaining good exposure without applying traction is not always possible. Injuries to the spleen in three of 18 patients reported by Eaton et al (2000) were caused by forceful traction on the transverse mesocolon from self-retaining retractors during abdominal vascular procedures.[35] They recommended that self-retaining retractors on the transverse mesocolon should be placed closer to the midline and forceful retraction in the left upper quadrant during exposure of the infra-renal abdominal aorta should be avoided. Hand-held retractors should always be placed carefully to avoid direct injury to the spleen and undue traction on these retractors should be avoided.[9,31]

In summary, in order to reduce the risk of splenic injury:

- Obtain good exposure and adequate visualisation by planning the surgical incision carefully and extending it if necessary, changing the position of the patient or the surgeon, and optimising illumination of the operation field.
- Avoid unnecessary traction and exercise great care when traction is necessary, in particular, medial traction on the lieno-omental and lieno-gastric bands and downward traction on the lieno-colic band.
- Place hand-held and self-retaining retractors carefully and gently and remove them when they are no longer required.
- Divide splenic ligaments and adhesions carefully and before applying traction, particularly to the stomach or transverse colon.

MANAGEMENT OF IATROGENIC SPLENIC INJURY

Once the spleen is injured, there are two options available: splenectomy or splenic conservation. Preservation of the spleen is clearly possible, particularly with minor capsular tears which constitute the commonest type of splenic injury.[24,30,52,58] Splenorrhaphy has also been demonstrated to be effective in severely damaged spleens.[59,60] Splenorrhaphy, however, is not always successful. Eaton et al (2000) attempted splenorrhaphy in seven of their 21 patients with splenic injury during abdominal vascular surgery.[35] All seven had grade one or two splenic injuries but continued bleeding made splenectomy necessary leading the authors to conclude that splenic preservation is unlikely to be successful (Table 2). Reilly et al (1994) only managed to preserve one spleen out of 23 injured during medial visceral rotation and Peck and Jackson (1964) found use of haemostatic agents or sutures to treat capsular tears to be ineffective.[2,36] Kusminsky et al (1984) on the other hand, managed to preserve all 36 spleens injured during colonic surgery.[58] Five out of six spleens injured during bariatric surgery were preserved.[30] Clearly, the more extensive the injury to the spleen the more difficult it is to preserve. Langevin et al (1984) found that it was possible to preserve four out of five spleens with an inferior pole capsular tear but only one out of three with a hilar injury.[24]

Most of the techniques of splenic preservation have been developed in the context of splenic trauma. Good visualisation

of the organ is essential to allow adequate assessment of the severity of injury. This requires complete removal of clot by gentle irrigation or grasping with forceps and possibly control of active bleeding by pressure on the splenic artery at the superior pancreatic margin.[66] Small capsular tears may not require any treatment. If a capsular tear is actively bleeding haemostatic agents such as fibrin adhesive, Gelfoam soaked in thrombin, microfibrillar collagen or absorbable regenerated cellulose with tamponade may be enough to achieve haemostasis.[67] Deeper lacerations require removal of devitalised tissue and approximation of parenchymal edges with sutures.[68,69] Suturing of the fibrous splenic capsule away from the wound margin to prevent tearing has also been used to achieve haemostasis.[66] Tribble et al (1987) have shown that absorbable polyglycolic or polyglactin mesh could be used to wrap the spleen and achieve splenic conservation.[70] Others have used an omental pouch as a means of splenorrhaphy.[71] Expanding haematomas should be opened and evacuated and bleeding controlled with suture ligation.[66] Splenic segmentectomy or hemisplenectomy may be necessary to preserve a more seriously injured spleen.[69,72] Other techniques such as use of Argon beam coagulation and high intensity ultrasound have also been tried.[73,74]

Severe splenic injury (grade four injuries) or haemodynamic instability may make attempts at splenic preservation unjustified and hazardous. Eaton et al (2000) argued that splenectomy may be preferable in patients undergoing vascular operations because of the risk of continued bleeding associated with anticoagulation and coagulopathies associated with multiple transfusions.[35]

Whether conserving the spleen, once it has been injured, confers any advantage is unclear. Splenic preservation has been shown to reduce late septic complications associated with splenectomy although the risk of fulminant post-splenectomy sepsis is low.[7,15,61] With respect to peri-operative infection, Duke et al (1993) found that the choice between splenectomy and splenic repair does not affect the risk for peri-operative infection following injury.[62] Blood transfusion, however, significantly increases the risk for peri-operative infection, respiratory complications and admission to the intensive care unit. This suggests that ideally, once the spleen is injured, measures should be taken to repair the injury and preserve the spleen but this should not be at the expense of excessive blood loss. Fujita et al (1996) found that blood loss in excess of 600ml was an independent risk factor for the development of post-operative infection.[40]

The debate about the role of splenic autotransplantation remains unresolved. Some investigators have shown that this is a safe and relatively easy procedure which results in improvement of some immunologic and reticuloendothelial functions.[76,77,78] However, the problem with autotransplantation is the evaluation of functional activity.[79] The observed improvement in immunologic and reticuloendothelial function does not appear to translate into a reduction in morbidity and mortality from overwhelming bacterial infection.[78,79] As a result, splenic autotransplantation has been almost completely abandoned.[77]

SUMMARY

Iatrogenic injury to the spleen is responsible for up to 40% of all splenectomies being performed. Although splenic injury is rare with most abdominal procedures, it is much commoner with open anti-reflux procedures, oesophagectomy, gastrectomy, left colonic surgery, left nephrectomy and abdominal vascular procedures. The incidence of splenic injury reported in the literature is believed to be an underestimate because of incomplete or inaccurate documentation. Splenectomy secondary to iatrogenic injury is associated with increased morbidity and mortality. Operating time, blood loss and hospital stay are also increased. Previous abdominal surgery, old age and obesity have all been reported to increase the risk of splenic injury. Most injuries to the spleen are caused by traction on the various peritoneal attachments to the spleen. Retractors and surgical instruments are responsible for the rest of the injuries. Capsular tears of the lower pole of the spleen are by far the commonest injuries sustained. Good exposure, careful use of retractors, and avoidance of traction on and early division of splenic ligaments and adhesions should lead to a decrease in splenic injuries. The increase in laparoscopic procedures should also result in a decrease in the incidence of iatrogenic splenic injuries. While attempts at splenic preservation after injury are commendable and often successful, these should not be at the risk of excessive blood loss.

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