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Operative Techniques in
General Surgery

Management of Intraoperative Splenic Injury

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Intraoperative splenic injury is reported to occur in approximately 0.01% of open laparotomies. Its incidence in re-operative surgery is much more significant and approaches 10%. The incremental morbidity associated with splenic injury is secondary to increased blood loss and operative time. In addition, splenectomy for a high-grade injury requiring segmental or complete splenectomy introduces a second set of potential complications such as infection and sepsis. Although there are a number of primary indications for splenectomy, up to 10% of splenectomies performed are secondary to an iatrogenic injury. Management of varying degrees of splenic injury requires prompt and appropriate decision making to ensure minimal additional morbidity and successful outcomes.

Risk Factors

There are a number of risk factors associated with iatrogenic splenic injury (Table 1). Patients who have had previous procedures in the left upper quadrant of the abdomen have approximately 20% incidence of splenic injury; several studies have demonstrated patients undergoing re-operative antireflux surgery to be at significant risk. Incisions that do not extend to the upper half of the abdomen are associated with higher incidence of injury, reflecting inadequate exposure and resulting in decreased ability to prevent traction injuries. The specific pathology for which the operation is being performed is also a major factor. For example, patients undergoing left nephrectomy have a higher incidence of splenic injury if being performed for a malignancy involving the superior pole of the kidney. Higher rates of injury have also been associated with morbid obesity and advanced age.

Mechanisms

Splenic injury in open abdominal surgery is more often associated with traction than a direct blow or a scalpel injury. Capsular tears are the most common type of injury, followed by lacerations, avulsion, and subcapsular hematoma. The inferior pole of the spleen is most commonly involved, given its ligamentous relationships with the tail of the pancreas, colon, and left kidney.

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Anatomy

The spleen is an important organ with immunological and phagocytic functions. It is situated in the posterior left upper quadrant behind the 9th, 10th, and 11th ribs. It is in close proximity to several organs (colon, left kidney, stomach, pancreas, and diaphragm) and is attached with a variety of ligaments (gastrosplenic, splenophrenic, splenocolic, and splenorenal). Except for the gastrosplenic ligament that contains the short gastric vessels, the attachments are avascular, enabling the rapid operative mobilization of the spleen.

The splenic hilum contains the splenic artery, which is the largest branch of the celiac artery. After crossing anterior to the superior pole of the left kidney, the artery divides into segmental or terminal branches. This allows the surgeon to effectively perform segmental splenic resection without vascular compromise to the remainder of the spleen. The primary venous drainage is via the splenic vein, which joins the mesenteric veins to constitute the portal vein.

Operative Management of Splenic Injury

Intraoperative management of a splenic injury can be divided into two broad categories: splenic salvage and splenectomy. Splenic salvage may enlist a variety of techniques to avoid the asplenic state with its associated potential for sepsis and substantial morbidity. The decision to pursue splenic salvage is dependent on the severity of the injury, the patient's hemodynamic stability, and the surgeon's experience.

Splenorrhaphy

The four techniques used in splenic repair are topical hemostasis, suture repair, partial resection, and mesh splenorrhaphy. The technique employed is determined by the grade of

Table 1 Risk Factors Associated with Splenic Injury

Previous surgery (adhesions)
Underlying pathology (invasive malignancy)
Location of primary incision (exposure of left upper quadrant)
Morbid obesity
Advanced age

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Table 2 Spleen Injury Scale

Grade		Injury Description
I	Hematoma	Subcapsular <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10% to 50% surface area; intraparenchymal, <5 cm in diameter
	Laceration	1 to 3 cm parenchymal depth not involving trabecular vessel
III	Hematoma	Subcapsular, >50% surface area; ruptured subcapsular or parenchymal hematoma
	Laceration	>3 cm parenchymal depth or involvement of trabecular vessels
IV	Laceration	Involvement of segmental or hilar vessels with devascularization
V	Laceration	Shattered spleen
	Vascular	Hilar vascular injury with complete devascularization of spleen

Adapted with permission from Cameron JL, Current Surgical Therapy, 2004.

splenic injury (Table 2). Nonbleeding injuries do not require intervention. Grade I and II injuries are treated with either direct pressure or a hemostatic agent. Grade III and IV injuries require suture or mesh repair. Segmental resection may be used for severe injuries with substantial hemorrhage isolated to either pole of the spleen.

Topical Hemostasis

Topical hemostatic agents should be readily available during operations with a high potential for splenic injury. Examples include Surgicel (Johnson & Johnson Inc., New Brunswick, NJ), Avitene (Alcon Laboratories, Humacao, Puerto Rico), and Gelform (Upjohn Co., Kalamazoo, MI). These agents' efficacy is limited to superficial capsular lacerations and small avulsions. Electrocautery may also be utilized in these circumstances, but larger injuries can actually be worsened if the coagulum is disrupted. The argon beam coagulator is particularly useful for large raw surfaces. Fibrin sealant with its thrombin component can be utilized as an adjunct.

Suture Repair

In the adult population, the thin splenic capsule requires pledgeted sutures to prevent capsular tears in suture repair of lacerations. For very large defects, PTFE and omentum can be used as a buttress for additional strength (Fig 1).

Mesh Repair

Mesh repair wraps the entire spleen with an absorbable mesh and is useful for severe injury involving an extensively de-

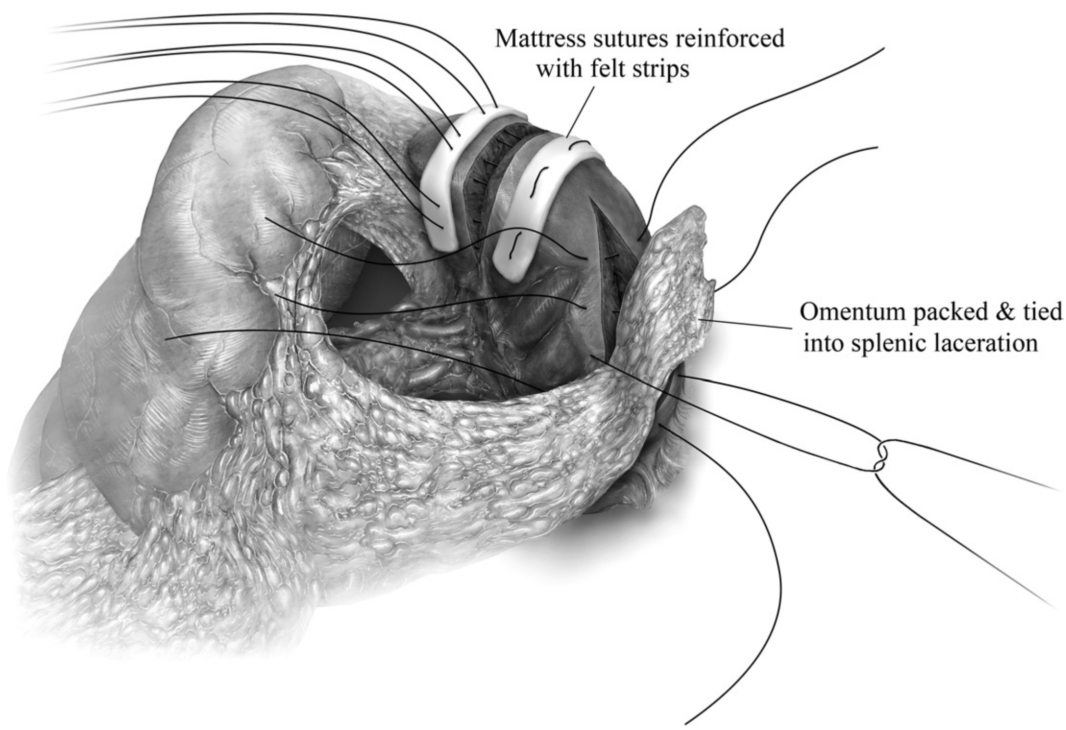

Figure 1 The capsule of the adult spleen is thin compared to that of the child. Thus, the placement of simple sutures will not suffice in the repair of damaged tissue. Horizontal sutures with the use of a buttress material, as shown in the illustration, are recommended. The sutures should not only incorporate the splenic capsule, but also approximately 1 cm depth of parenchymal tissue. Deep splenic lacerations can also be repaired without the use of synthetic material. The omentum is an excellent option to provide buttress support and is secured using the same horizontal mattress sutures. The omentum must be mobilized on a vascular pedicle to ensure the repair does not become disrupted from ischemia. The strip of omentum is created by either a series of clamping and suture ligations or advanced energy sources. The advantage of the omentum is its use as a packing material within deep lacerations.

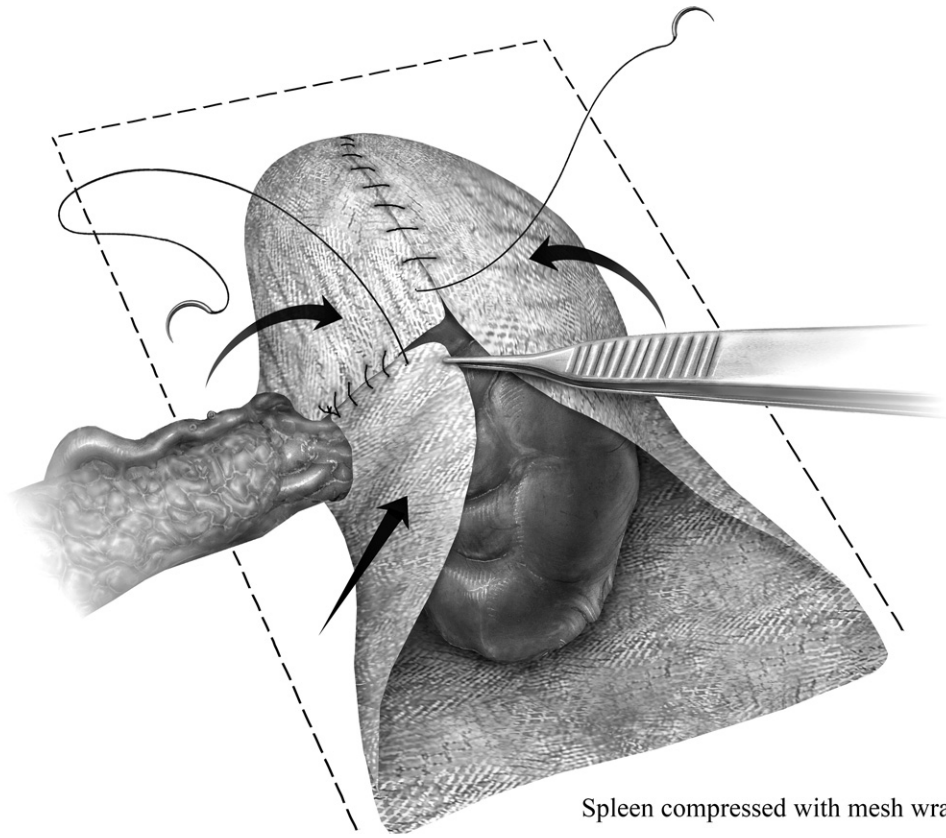

Figure 2 The use of absorbable mesh is preceded by the complete mobilization of the spleen from its ligamentous attachments, as described with the illustrations for a complete splenectomy. The size of the mesh is dependent on the size and volume of the spleen. The complete mobilization of the spleen will leave the hilar vessels as the sole attachment to its medial aspect. The mesh can be easily be placed under the spleen. The pitfall that must be avoided is to neglect the hilar vessels as the mesh is brought anteriorly for suturing to the splenic capsule. A keyhole must be created to accommodate the splenic artery and vein to avoid ischemia. The spleen is then wrapped in the mesh that is sized accordingly and sutured to the anterior surface of the spleen. The mesh must be well approximated to take advantage of its tamponade effect. An inappropriate small mesh size will place tension on the suture line and will cause the repair to come apart, resulting in more hemorrhage.

nuded splenic capsule. Suturing of the absorbable mesh to itself and to the remaining splenic capsule provides compressive hemostasis. The surgeon tailors the wrap medially to accommodate the hilar vessels (Fig 2).

Segmental Resection

Partial or segmental resection of the spleen is possible given the segmental blood supply to the organ. This approach is ideal if vascular injury has already allowed the splenic tissue to demarcate. For parenchymal injury, the segment of spleen to be removed can be intentionally demarcated by ligating the corresponding segmental artery at the hilum. Segmental resection is performed bluntly with electrocautery, or with the ultrasonic shears, followed by a pledgeted repair of the parenchyma (Fig 3).

Splenectomy

Total splenectomy remains the safest and most conservative approach to unintended injury, particularly for the surgeon inexperienced in splenic salvage techniques, or in complex operations where the impact of rebleed or infection would be more profound. A successful outcome is dependent on size and mobility of the spleen, presence of adhesions, degree of bleeding, and underlying pathology (Fig 3).

Postoperative Management

The placement of closed suction drains after management of splenic injury is not required unless there is a concern for a pancreatic tail injury, persistent coagulopathy, or issues related to the primary drain. Even if a splenectomy is required, the surgeon has to be concerned with a second set of possible complications (Table 3). Laboratory tests may demonstrate a reactive thrombocytosis. This only requires treatment if the patient has a clotting disorder; some advocate antiplatelet agents if postoperative platelet counts exceed one million per cubic milliliter.

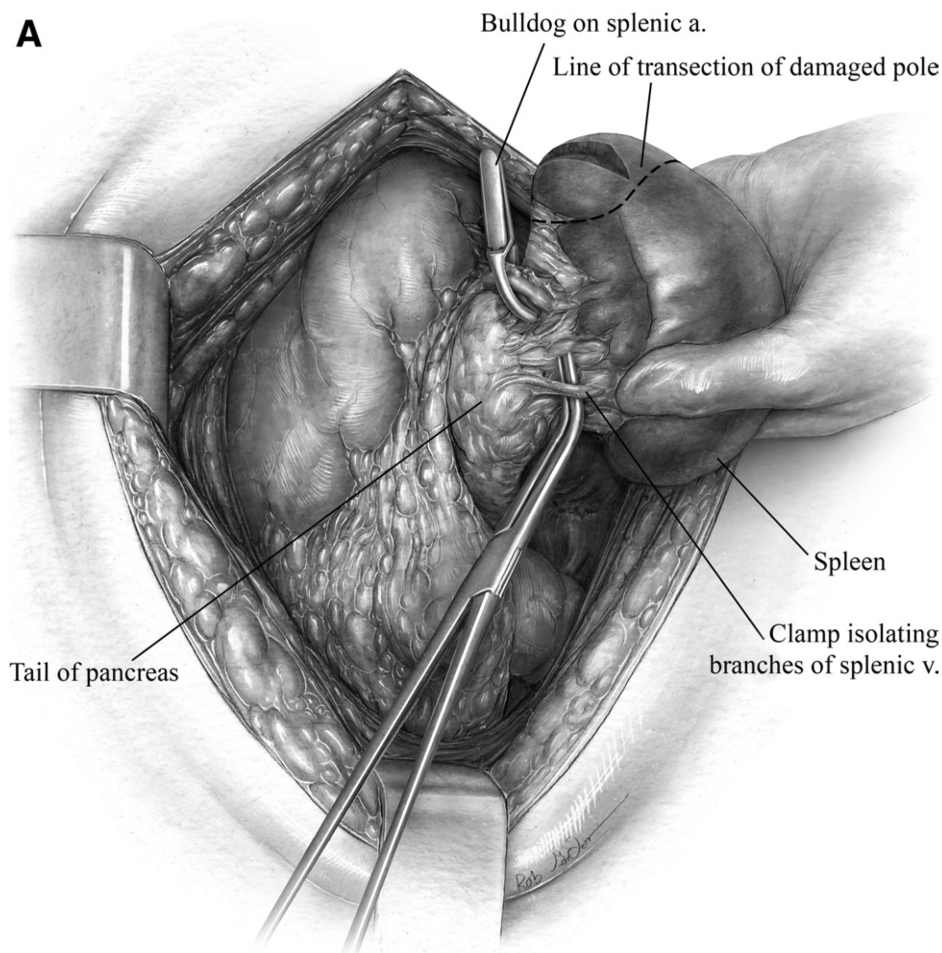

Figure 3 (A) Severe lacerations of the spleen can be repaired with segmental resection or treated with splenectomy, depending on the location of the injury. Involvement of the center of the spleen and/or hilum is a contraindication to this approach, whereas involvement of either pole may be controlled with a segmental resection. After dividing the ligaments associated with its convex surface, the spleen is mobilized into the operative field. The gastrosplenic ligament is then divided and the short gastric vessels and ligated to expose the underlying splenic artery. The main splenic artery splits into several segmental branches that can be individually isolated. In this illustration, a segmental vessel associated with the spleen's lower pole has been isolated with a right angle clamp; a bulldog clamp has been applied to an upper pole vessel in preparation for its amputation and pledgeted repair. Once the spleen has been properly mobilized, the clamps may be applied to either side of the gastrosplenic ligament. a. = artery; v. = vein.

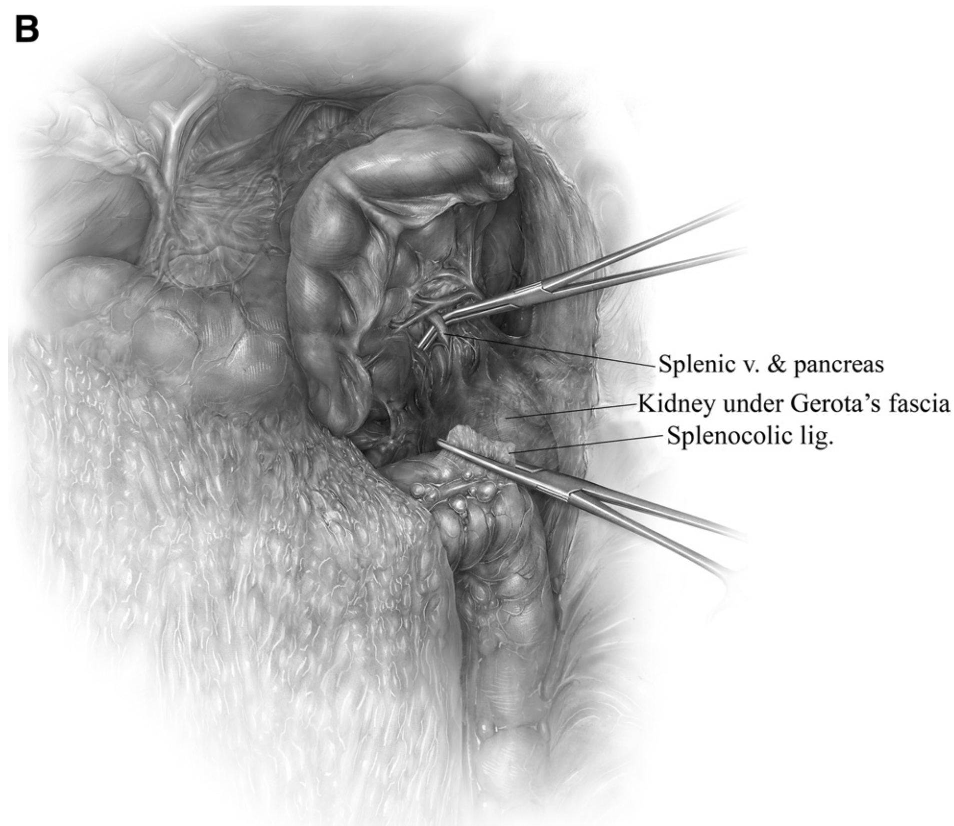

Figure 3 (Continued) (B) The first step in a successful splenectomy or splenorrhaphy is to obtain appropriate exposure to left upper quadrant, usually by extension of the incision already present. Exposure cannot be compromised to avoid further iatrogenic injury. To deliver the spleen into the wound, the first of the avascular ligaments, the splenorenal ligament, is divided. With a traumatic injury, the resultant hematoma frequently facilitates this dissection. The spleen can then be rotated medially exposing the splenocolic and splenophrenic ligaments. It is important to note that underlying disease states such as portal hypertension can vascularize these ligaments. After the ligation of the segmental artery, the devascularized portion of the spleen will become demarcated by ischemic changes. The devascularized tissue can then be removed by a variety of techniques. Electrocautery or ultrasonic shears may be utilized as a hemostatic energy source or the tissue can be easily separated using finger fracturing. The intrasplenic vessels that become exposed on the cut surface are controlled with clips or suture ligations. After the injured splenic tissue is removed, a suture repair is needed, utilizing the same pledgeted manner previously described. Additional topical hemostasis agents may be applied as needed before returning the spleen back to its anatomical position. In this illustration, a posterior approach to the vessels facilitates their clamping without injury to the pancreas. To facilitate further exposure, the splenocolic ligament is divided in a similar fashion. If electrocautery is utilized, care has to be taken to avoid the superior border of the transverse colon to prevent thermal injury. Other potential pitfalls at this point include injury to the tail of the pancreas and to hilar vessels. The gastrosplenic ligament is then incised. Ligation of the short gastric vessels facilitates access to the lesser sac and pancreas. A potential pitfall for this step is injury to the greater curvature of the stomach or not recognizing the superiormost short gastric vessels. The splenic artery courses along the superior margin of the pancreas and can be easily palpated. The tissue around the artery is carefully incised allowing the artery to be clamped and ligated with sutures or with a stapler. Ligation of the artery before the splenic vein allows the blood in the spleen to drain, conserving red blood cells and reducing the size of the spleen. v. = vein; lig. = ligament.

C

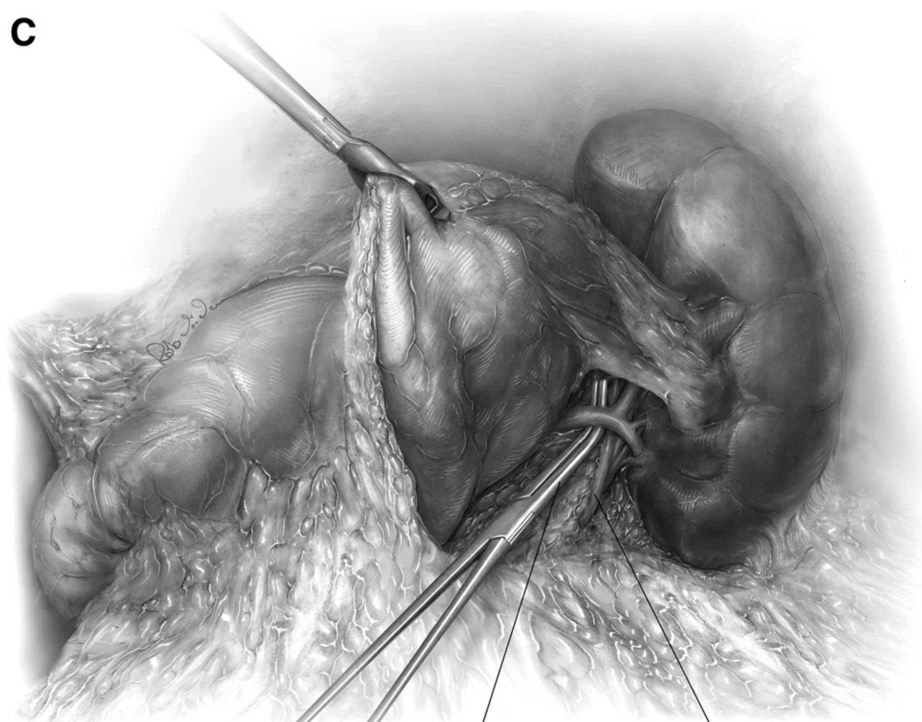

Figure 3 (Continued) (C) With the arterial blood supply to the spleen having been completely divided, the splenic vein lying underneath the artery is dissected free to allow adequate clamping and ligation. This essentially frees the majority of the spleen with the exception of small peritoneal attachments that can be easily incised. After the spleen is removed, the splenic bed should be inspected for hemostasis. a. = artery; v. = vein.

Table 3 Postoperative Complications Associated with Splenic Injury Repair/Splenectomy

Infectious	Noninfectious
Pneumonia	Pleural effusion
Subphrenic abscess	Hemorrhage/hematoma
Sepsis	Gastric injury
	Colon injury
	Pancreatitis
	Pancreatic tail injury/pancreatic fistula

Conclusion

Prevention of injury is grounded in knowledge of anatomy. The surgeon should know which operations and exposures have the potential to injure the spleen and should have the ability to address any iatrogenic splenic injury. Splenectomy is not required in all circumstances. The appropriate decision making has to be prompt to minimize postoperative morbidity.

Suggested Reading

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