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Review Article

From Material Science to Bedside Diagnosis and Therapy: A Comprehensive View of Surgical Drains in Abdominal Surgery

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Abstract:

The application of surgical drains in the abdominal cavity remains a subject of persistent debate in modern surgery, requiring a careful balance between traditional clinical utility and contemporary Enhanced Recovery After Surgery (ERAS) protocols. This paper evaluates the technical specifications, physical principles, and strategic clinical applications of various drainage systems, emphasizing that the decision to drain must transition from routine use toward evidence-based selectivity. Central to this analysis is the interplay between material science and fluid dynamics; notably, Poiseuille's Law dictates that fluid flow is directly proportional to the fourth power of the drain's radius (r4), meaning small increases in French (Fr) size significantly enhance the evacuation of viscous effluents like pus or blood. Drains continue to serve as essential "silent sentinels," providing critical early diagnostic data on hemorrhage, anastomotic integrity, and specific biochemical markers such as amylase or bilirubin before systemic symptoms appear. While materials like silicone are preferred for their minimal tissue irritation, latex is strategically utilized when the induction of local inflammation is necessary for sinus tract formation. Despite these benefits, the physical presence of a drain can influence recovery by increasing the risk of surgical site infection (SSI), causing pressure necrosis, or interfering with early patient mobilization. Ultimately, surgical success depends on matching the specific pathophysiological needs of the patient with the appropriate drainage modality, thereby optimizing safety while minimizing the morbidity associated with prolonged drainage.

Key words: abdominal surgery; surgical drains; eras protocols; poiseuille's law; material science; abdominal surgery; drainage mechanics; postoperative complications

Introduction

The application of surgical drains in the abdominal cavity remains a subject of persistent debate in modern surgery. While ERAS (Enhanced Recovery After Surgery) protocols have significantly curtailed their routine use, drains continue to serve as essential therapeutic tools and critical "diagnostic windows" in specific clinical scenarios [1]. This paper analyzes the technical specifications, strategic placement, and diagnostic significance of abdominal drains in contemporary practice. Furthermore, understanding the interplay between material science and fluid dynamics is paramount, as the surgical success often depends on selecting the appropriate drainage modality to match the specific pathophysiological needs of the patient [2-4].

1. Classification and Mechanics of Action

Surgical drains are primarily categorized according to their mechanism of action [5-7], which dictates their specific clinical application:

• Passive Drains (e.g., Penrose): These rely on capillarity, gravity, and intra-abdominal pressure. The effluent typically exits along the external surface of the drain.

• Active (Suction) Drains (e.g., Jackson-Pratt): These utilize negative pressure to evacuate fluid from "dead spaces". Closed systems are generally preferred, as they are associated with lower infection rates compared to open drains.

2. Sizing and the French Scale

In clinical practice, the diameter of a drain is quantified using the French scale (also known as the Charrière system) [8]. Unlike the Gauge system used for needles—where the diameter is inversely proportional to the gauge number—the French scale is directly proportional to the external diameter of the drain [8, 9].

• Formula: 1 Fr = 1/3 mm.

• Example: An18 Fr drain has an external diameter of exactly 6 mm.

3. The Physics of Drainage and Poiseuille's Law

The literature emphasizes that fluid flow through a surgical drain is not stochastic but follows Poiseuille's Law [10]. The flow rate of a fluid is directly proportional to the fourth power of the drain's radius (r4). This implies that even a minimal increase in the French size (e.g., from 12 Fr to 15 Fr) dramatically enhances the evacuation velocity of viscous effluents such as pus or blood. Furthermore, shorter drains offer lower resistance and superior efficiency compared to unnecessarily long drainage tubes.

4. Bedside Diagnosis: The Effluent as a Clinical Messenger

The most critical aspect of the drain is its role as a "silent sentinel" [11-13]. The contents of the collection bag provide immediate biochemical and visual data:

• Hemorrhage: A sudden rush of bright red blood or high-volume output.

• Anastomotic Integrity: Presence of enteric content or feces confirms a leak.

• Biochemical Markers: Testing the effluent for amylase or bilirubin levels allows for the objective diagnosis of specific fistulas (e.g., Grade A vs. Grade B pancreatic fistulas) before systemic symptoms appear.

5. Indications and Strategic Application

The modern surgeon must decide not just how to drain, but if to drain. The decision on drainage is divided into prophylactic and therapeutic [14-15]:

• Prophylactic Utility: Indicated in high-risk scenarios such as pancreaticoduodenectomies or complex liver resections where early detection of a biliary or pancreatic fistula is paramount.

• Therapeutic Intent: To evacuate an existing abscess or infected collection.

• When to Avoid: Routine drainage is now discouraged in uncomplicated appendectomies or cholecystectomies. Evidence suggests they may increase the risk of retrograde infection (the "two-way street" effect) without necessarily preventing leaks.

6. Specific Surgical Indications in Abdominal Surgery

The literature provides precise recommendations for drain placement in various abdominal procedures [1, 3-5]:

• Hepatic Drainage: Following liver transection, perihepatic drainage is indicated due to the risk of biliary leakage from the cut parenchymal surface.

• Cholecystectomy: Subhepatic drainage is recommended only in cases of visible bile leakage from the gallbladder bed that could not be controlled by other means.

• Pancreatic Surgery:

O In pancreatic injuries, a drain is placed in the pancreatic bed to evacuate pancreatic juice and remains in situ until drainage completely ceases.

O In necrotizing pancreatitis associated with an abscess, sump drains are preferred as they facilitate the evacuation of liquefactive necrosis and promote the formation of a stable drainage tract.

• Biliary Anastomoses: Due to frequent, albeit temporary, leakages, drainage is routinely beneficial in hepaticojejunostomies and similar reconstructive procedures.

7. Functional Classification of Drainage Systems

In surgical practice, the fundamental classification of drains is based on the force that drives the evacuation of the effluent, categorizing them into passive (relying on gravity and capillarity) and active (utilizing negative pressure or vacuum). However, for a comprehensive clinical evaluation, it is essential to consider the method of collection as well as the safety mechanisms governing the flow [2].

7.1. Open vs. Closed Systems

This classification refers to the destination of the drainage effluent and the associated risk of external contamination.

• Open Systems: Drains (such as the Penrose or corrugated drain) discharge fluid directly onto gauze dressings or into an improvised bag.

O Clinical Concern: There is direct communication between the external environment and the abdominal cavity. The risk of retrograde infection is high, as bacteria from the skin and dressings can "ascend" along the drain.

• Closed Systems: The drain is connected to a sterile bag or a specialized reservoir (such as the Jackson-Pratt or Bellovac).

O Advantages: These systems offer a reduced risk of nosocomial (hospital-acquired) infections and allow for easier, more precise monitoring of the output volume.

7.2. Suction vs. Passive (Non-Suction)

This classification is based on the physical force that drives the evacuation of fluid.

• Passive (Non-Suction): These drains rely on natural forces, such as gravity, capillarity, and the intra-abdominal pressure generated by respiration and intestinal peristalsis.

O Examples: Kehr (T-tube) or Penrose. It is important to note that if the collection bag is positioned above the level of the abdomen, the drainage flow will cease.

• Suction (Active/Aspirational): These systems utilize an artificially created negative pressure (vacuum).

O Examples: Redon or Hemovac. The vacuum helps in "apposing" tissue to tissue, effectively eliminating dead spaces; however, excessive vacuum pressure can damage sensitive visceral structures.

7.3. Sump-Suction vs. Closed-Suction

This represents the most critical technical distinction for preventing iatrogenic damage to internal organs.

• Closed-Suction: A straightforward system consisting of a single lumen connected to a vacuum source.

O Risk: If the vacuum pressure becomes excessive, or if adjacent tissue (e.g., omentum or the intestinal wall) occludes the drain's side-holes, the vacuum can "suck" the tissue into the lumen. This may result in localized pressure necrosis or visceral perforation.

• Sump-Suction: A dual-lumen system (e.g., Salem Sump or Axiom).

O Mechanics: The primary lumen evacuates fluid, while the secondary (smaller) lumen serves as an air vent. The air entering through this vent prevents the formation of an excessive vacuum at the tip of the drain.

O Clinical Significance: This configuration allows for continuous suction without the risk of the drain "adhering" to the gastric or intestinal mucosa, thereby preventing erosive complications.

The following Table 1 delineates the functional taxonomy of drainage systems, highlighting their underlying mechanisms, clinical advantages, and inherent risks [2]:

Type	Characteristics	Primary Risk / Drawback	Key Advantage
Open	Effluent exits onto gauze/dressings	High risk of infection (retrograde)	Simple and cost-effective.
Closed	Effluent collects in a sterile reservoir	Risk of lumen occlusion (fibrin)	Sterility and precise monitoring.
Passive	Relies on gravity and capillarity	Inefficient for high-viscosity fluid	Minimal tissue trauma.
Active (Closed-Suction)	Utilizes negative pressure (vacuum)	Potential for visceral organ erosion	Eliminates "dead space".
Active (Sump-Suction)	Dual-lumen with air-vent system	Operational noise ("whistling")	Safe continuous suction.

Table 1: Functional Classification of Drainage Systems: Mechanism, Benefits, and Clinical Risks

While the preceding table defines the physical principles of drainage, the following overview (Table 2) provides a detailed taxonomy of specific drainage systems and tubes, integrating their material properties with concrete indications in abdominal surgery [2, 4, 5].

Drain / Tube Name	Material	Mechanism of Action	Primary Clinical Application in Abdomen (C1)
Penrose*	Latex or Silicone	Passive (Capillarity)	Drainage of subcutaneous spaces and formation of a sinus tract.
Jackson-Pratt (JP)***	Silicone (Silastic)	Active (Closed Suction)	Deep collections; low pressure prevents intestinal trauma.
Salem Sump#†	PVC	Active (Sump-Suction)	Gastric decompression; air vent prevents mucosal damage.
T-tube (Kehr)††	Latex or Silicone	Passive (Gravity)	Drainage and stenting of the common bile duct.
Pigtail Catheter**	Polyurethane / Teflon	Passive/Active (Spiral tip)	Percutaneous abscess drainage under US/CT guidance.
PEG (Percutaneous Endoscopic Gastrostomy)††	Silicone or Polyurethane	Passive (Fixation disk)	Long-term enteral nutrition directly into the stomach; placed endoscopically.
Exudrain / Bellovac***	PVC or Silicone	Active (High Vacuum)	Drainage of large "dead spaces" with constant negative pressure.
Urinary Catheter (Foley)**	Latex or Silicone	Passive (Gravity)	Diuresis monitoring and bladder decompression during surgery.
Fine Bore Feeding NGT†	Polyurethane / Silicone	Passive (Enteral Access)	Long-term feeding; smaller diameter reduces the risk of esophagitis.
Feeding Jejunostomy††	Polyurethane	Passive (Direct Access)	Surgically placed tube into the jejunum for feeding in upper GIT obstructions.
Yeates*	PVC	Passive (Multiple Channels)	Capillary drainage for diffuse intraperitoneal collections.
Axiom Sump#	Silicone	Active (Sump-Suction)	Continuous evacuation of high-volume viscous effluent.
Corrugated Drain*	PVC or Rubber	Passive (Gravity)	Drainage of the gallbladder bed or abdominal wall infections.
PTBD Catheter**	Latex / Hydrogel	Passive (Stenting)	Transhepatic biliary drainage for malignant or benign obstructions.
Ryle's Tube†	PVC or Silicone	Passive (Decompression)	Short-term gastric aspiration or postoperative decompression.
Peritoneal Catheter††	Silicone	Passive (Gravity)	Chronic drainage of malignant or cirrhotic ascites.
Blake Drain***	Silicone	Passive (Fluted Channels)	Drainage along the entire surface; minimal risk of fibrin occlusion.

Table 2: Comprehensive Overview of Abdominal Drains and Tubes (C1)

Note: * Open Drains; ** Closed Passive Drains; *** Closed Suction Drains; # Sump Suction Drains; † Gastrointestinal Drains: Nasogastric Tubes (NGT); †† Gastrointestinal Drains

8. Impact on Wound Healing and Clinical Complications

While the primary objective of surgical drainage is to protect the patient, these systems are associated with inherent risks [16-18]. The literature emphasizes that the physical presence of a drain can have a significant influence on the recovery process.

• Surgical Site Infection (SSI): A drain brought out through the main incision significantly increases the risk of SSI. Therefore, to maintain the integrity of the primary wound, drains should always be placed through a separate, dedicated stab incision.

• Pressure Necrosis and Erosions: Prolonged contact with rigid materials—specifically older PVC formulations—can cause pressure-induced decubitus on the intestinal wall or adjacent major blood vessels, potentially leading to iatrogenic fistulas or secondary hemorrhage.

• Visceral and Mobilization Issues: The presence of a drainage tube may cause localized irritation of the peritoneum and can interfere with the early mobilization of the patient, which is a core tenet of modern ERAS protocols.

• Drain Migration and Loss: Inadequate fixation to the skin may result in the drain migrating into the abdominal cavity or its premature dislodgement.

• Lumen Occlusion: The formation of fibrin plugs is most common in small-diameter drains (low French size), particularly when draining protein-rich exudate or viscous fluids.

9. Materials and Tissue Reaction

As foreign bodies, all surgical drains elicit some degree of tissue response [19-21], which can be strategically utilized or minimized based on the material selected:

• Silicone (Silastic): Elicits minimal inflammation. Its soft consistency significantly reduces the risk of erosion into adjacent visceral organs.

• Latex: Often selected when the surgical objective is the intentional induction of local inflammation. This reaction is necessary for the formation of a robust sinus tract, which ensures continued drainage even after the tube is removed.

• PVC (Polyvinyl Chloride): A more rigid material typically used for large-lumen drains. While effective for high-volume evacuation, its stiffness can be more traumatic to the surrounding tissues.

• Red Rubber: Historically used as a routine alternative for short-term drainage, red rubber is found to be the most irritant of the materials studied. While its high reactivity promotes rapid tract formation, its significant inflammatory potential makes it less desirable than latex or silicone unless those materials are unavailable.

10. Clinical Pearls for Abdominal Drain Management

Effective management of abdominal drainage systems requires the integration of theoretical principles of fluid dynamics with specific clinical maneuvers that optimize diagnostic accuracy and patient safety. The following "clinical pearls" summarize key technical finesses that allow the surgeon to prevent common postoperative errors and maximize the potential of the drainage system [2, 10].

• Air Bubbles and T-tubes (Cholangiography): When assessing the patency of the biliary tree via cholangiography, air bubbles within the system can mimic calculi (appearing as filling defects). Clamping the T-tube for 24 hours prior to the procedure reduces this risk, as the rising biliary pressure helps displace and expel the air.

• Sump Drainage and "Whistling": In Salem Sump tubes, the blue air-vent remains patent only if a continuous "whistling" sound is audible while the tube is connected to suction. If this sound ceases, the vent is likely occluded, which significantly increases the risk of gastric mucosal erosion due to excessive vacuum.

• The Physics of Flow (Poiseuille's Law): Fluid flow through an abdominal drain is directly proportional to the fourth power of the drain's radius (r4). Consequently, increasing the diameter from 12 Fr to 15 Fr dramatically enhances the evacuation velocity of high-viscosity effluents, such as pus or thick exudate.

11. Removal of Drains

A drain should be removed as soon as its clinical purpose has been fulfilled, as prolonged retention significantly increases the risk of secondary complications [2, 22].

• Removal Criteria: Clinical data strongly suggest that the timely withdrawal of surgical drains—specifically when daily production is under 50 mL and the effluent remains serous (non-biliary and non-hemorrhagic)—is linked to a significant reduction in surgical site infections, the prevention of iatrogenic fistulas, and a decrease in overall hospital stay [22].

• "Shortening" Technique: In certain abdominal procedures, a drain may be withdrawn incrementally (shortened) over several days. This technique encourages the drainage tract to heal and close from the deeper layers toward the surface, preventing the entrapment of fluid collections [2].

Conclusion

The cornerstone of effective surgical drainage is balancing the risks of tissue irritation against the clinical benefits of early complication detection. A profound understanding of the physical properties of materials and the mechanics of drainage systems, as documented in foundational surgical literature, empowers surgeons to make precise instrumental choices in their daily practices.

Ultimately, the decision to drain must be tailored to each patient, transitioning from routine application to evidence-based selectivity. Integrating the laws of physics, such as Poiseuille's law, with an acute awareness of material-tissue interactions enables the modern abdominal surgeon to optimize patient safety and minimize the morbidity associated with prolonged drainage.

Declarations

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Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation: Ilija Golubovic, Aleksandar Vukadinovic, Milan Radojkovic, Vanja Pecic, Jovan Jovanovic, Aleksandar Pavlovic, Marko Stojanovic

Performed data acquisition, as well as provided administrative, technical, and material support: Ilija Golubovic

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

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References

1. Lim SY, Kang JH, Jung MR, Ryu SY, Jeong O. (2020). Abdominal Drainage in the Prevention and Management of Major Intra-Abdominal Complications after Total Gastrectomy for Gastric Carcinoma. *J Gastric Cancer*. 20(4):376-384.
2. Ngo QD, Lam VWT, Deane SA. (2020). Drowning in Drainage: The Liverpool Hospital Survival Guide to Drains and Tubes. *Surgical Drains Publishing*.
3. Yoon S-J, Yoon S-K, Jung J-H, Han I-W, Choi D-W, Heo J-S, Shin S-H. (2021). Realistic Advantages of Early Surgical Drain Removal after Pancreatoduodenectomy: A Single-Institution Retrospective Study. *Journal of Clinical Medicine*. 10(12):2716.
4. Petrowsky H, Demartines N, Rousson V, Clavien PA. (2004). Evidence-based value of prophylactic drainage in gastrointestinal surgery: a systematic review and meta-analyses. Ann Surg. 240(6):1074-1085.
5. Alhatm M, Alaslamy YM, Alshahrani MAJ, et al. (2025). Active versus Passive Drainage after Intra-abdominal Procedures: A Systematic Review and Meta-analysis *Journal of Advanced Trends in Medical Research*. 2(1):10-14.
6. Han Y, Wu Z, Song J, Zhang Q, Wei L, Lu H. (2024). Effect of passive versus active abdominal drainage on wound infection after pancreatectomy: A meta-analysis [retracted in: Int Wound J. 2024 Oct;21(10):e70113. *Int Wound J*. 21(3):e14755.
7. Zhang X, Li T, Li X, Chen J, Zhang F. (2023). Comparison of the complications of passive drainage and active suction drainage after pancreatectomy: a meta-analysis. *Front Surg*.10:1122558.
8. Daga K, Milward GD, Pintos Dos Santos D, Edwards DW, Laasch HU. (2025). A standardised comparison of chest and percutaneous drainage catheters to evaluate the applicability of the 'French' sizing units. *Sci Rep*. 15(1):1601. Published 2025 Jan 10.
9. Celik E, Goertz L, Henze J, et al. (2023). Evaluation of viscosities of typical drainage fluids to promote more evidence-based catheter size selection. *Sci Rep*. 13:22178.
10. Ostadfar A. (2016). Fluid mechanics and biofluids principles. In: Ostadfar A, ed. *Biofluid Mechanics*. Academic Press; 1-60.
11. Goldenshluger M, Margalit C, Kodesh A, Katz E, Hazzan D, Segev L. (2023). Bedside Drainage of Perianal Abscesses: Is It Safe and Effective?. *Isr Med Assoc J*. 25(7):473-478.
12. Luo K, Shi W, Chen Y, Wang B, Yao J, Yang X. (2020). A Method for Monitoring the Working States of Drainage Tubes Based on the Principle of Capacitance Sensing. *Sensors (Basel)*. 20(7):2087. Published 2020 Apr 8.
13. Meckler A, Künert S, Poggi L, et al. (2025). Intelligent surgical drainage - digitizing the analysis of drainage fluid in patients with surgical drains. *PLoS One*. 20(7):e0325072. Published 2025 Jul 28.
14. Margioula-Siarkou C, Almperis A, Almperi EA, et al. (2025). Prophylactic and Therapeutic Usage of Drains in Gynecologic Oncology Procedures: A Comprehensive Review. *J Pers Med*. 15(6):254. Published 2025 Jun 16.
15. Groothoff MS, Kelley MS, De Simone B, Deeken G, Biffl WL. (2025). Prophylactic drain placement after emergency general surgery procedures? A scoping review of the literature challenging common practice. *Am J Surg*. 247:116462.
16. Deshpande, Saha. (2025). Impact of drain use on postoperative outcomes: a prospective study comparing drain placement versus no drain in surgical patients. *Int J Environ Sci*. 11:789-794.
17. Gadiraju GK, Prospero MR, Tobias F, Malek AJ, Reiche E, Broyles JM. (2025). Understanding the Impacts of Surgical Drains on Postoperative Pain and Quality of Life. *Plast Reconstr Surg Glob Open*. 13(1):e6474. Published 2025 Jan 27.
18. Loon MM, Mohamed EH, Oliveira Souza Lima SR, Hassan BD, Abbas T. (2024). Comparative Effectiveness of Surgical Drainage Techniques and Postoperative Interventions for Reducing Complications: A Systematic Review of Randomized Controlled Trials. *Cureus*. 16(11):e73364. Published 2024 Nov 10.
19. Ramesh BA, Evans JT, Marietta M, et al. (2026). Suction drains. In: StatPearls [Internet]. *StatPearls Publishing*; Accessed March 23, 2026.
20. Apalakis A. (1976). An experimental evaluation of the types of material used for bile duct drainage tubes. *Br J Surg*. 63(6):440-445.
21. Hrubovčák J, Dudík I, Voves J, et al. (2022). Latex and silicone drains in surgery − is the ban on rubber drains really a step forward or rather a step back?. atexv a siiv dr v chirurgii e a pryžvh dru pravdu re dpředu eb spše pět. *Rozhl Chir*. 101(11):525-529.
22. Salib M, Salib J, Kondilis E, Music A, Phillips M. (2025). Optimizing Surgical Drain Removal: A Narrative Review of Timing, Criteria, and Evidence-Based Practices. *Cureus*. 17(10):e94492. Published 2025 Oct 13.

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