Common haemostatic techniques used in surgical practice

Abstract

Intraoperative bleeding can be difficult to manage and is associated with worse patient outcomes. Good intraoperative haemostasis by the surgeon is a key factor in ensuring a bloodless field and reducing intraoperative blood loss. There is a myriad of mechanical, thermal and energy-based techniques available to use, each of which has their own benefits and drawbacks. The decision of which to use will depend on patient and procedural factors as well as the surgeon's preference. This article reviews techniques commonly used in surgical practice to maintain intraoperative haemostasis.

Key words: Bleeding; Blood loss; Coagulation; Diathermy; Electrosurgery; Haemostasis

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Introduction

Bleeding can occur during any surgical procedure, and large intraoperative blood loss is associated with worse patient outcomes and increased cost and length of admission (Karkouti et al, 2004; Stokes et al, 2011). Intraoperative bleeding also makes surgery technically challenging; not only can blood obscure the operative field, but during laparoscopic and endoscopic surgery haemoglobin absorbs the light needed to visualise visceral structures (Bosschaart et al, 2014) further hindering the operator. Bleeding may be minor and arise from small, dermal vessels, but it can originate from larger vessels resulting in significant and rapid blood loss. In either case, it is important for those performing operations to have a solid understanding of the factors that contribute to bleeding. These can manifest preoperatively or intraoperatively and can be further exacerbated during the immediate postoperative period. A range of techniques is available to manage bleeding when it occurs, and each has its own associated strengths and weaknesses.

This article focuses on minimising blood loss through effective intraoperative haemostasis and the available mechanical, thermal and energy-based techniques used to achieve this. The advantages and disadvantages of the techniques are discussed and procedures that frequently use them are highlighted.

General principles

Intraoperative blood loss can be attributed to a range of factors, many of which present during the perioperative period. A key element is in the management of patients with acquired and congenital coagulopathies (Kozek-Langenecker et al, 2017). Correction of coagulopathy by withholding anticoagulants is common practice and in certain cases reversal agents are indicated. In major trauma, correction of acidosis and hypothermia helps to reduce the acquired coagulopathic state (Mitra et al, 2012). However, while coagulopathies contribute to blood loss, more often the main cause of bleeding is the surgical intervention itself (Curnow et al, 2016).

While minimally invasive surgical approaches reduce blood loss (Simillis et al, 2019), it is still important that good use of anatomically avascular planes is achieved. For example, during percutaneous renal surgery, use of the plane between the anterior and posterior renal artery branches (Brödel's line) helps to prevent bleeding that would otherwise be difficult to control (Macchi et al, 2018). Furthermore, knowledge of regional vascular anatomy is important as potential sites of bleeding can be anticipated and managed appropriately. This is particularly pertinent for procedures involving the scalp as it has a rich blood supply (Cormia, 1963).

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In addition to good use of anatomy, physiological techniques, such as permissive hypotension, are effective at minimising blood loss (Kudo et al, 2017). Pharmacological methods can also be used, with tranexamic acid administration during major surgery minimising the need for transfusion (Shah et al, 2020) and subcutaneous adrenaline use during skin graft surgery reducing intraoperative bleeding as well as the operative time (Gacto et al, 2009).

Mechanical

A surgeon's initial action on encountering bleeding is often to apply direct pressure to the area. This is for two reasons: first, direct pressure maintained for 15–20 seconds may be sufficient to control the bleed (Samudrala, 2008) and second, it minimises blood loss while gathering the instruments for a more definitive haemostatic technique. Pressure dressings are also commonly used, particularly following varicose vein surgery. Direct pressure alone carries the risk of rebleed if the clot is displaced and will not control bleeding from larger vessels, which will require the cut ends to be ligated (**Table 1**).

Sutures

Sutures date back to neolithic times when they are thought to have been used for wound approximation (Mackenzie, 1973). In clinical practice, catgut and silk were the first widely used suture materials (Holder, 1949) and remained popular until the late 1960s when synthetic suture materials became available. Sutures can be described according to their absorbability (absorbable vs non-absorbable), filament type (monofilament vs multifilament), material and size. Sutures are available mounted onto a variety of needles or as ties. The myriad types of suture reflect their versatility and widespread use for tissue approximation and haemostasis in both open and laparoscopic surgery.

Prolene, a polypropylene suture, was developed in 1969 (**Figure 1**); it is a non-absorbable suture that exerts minimal tissue trauma while providing long-term durability. These properties are useful in vascular anastomoses and vessel repair, making it popular in cardiac and vascular surgery (Calhoun and Kitten, 1986) where it is associated with a lower incidence of false aneurysms (Gaspar et al, 1983).

Shortly after, Vicryl (polyglactin 910 suture) was developed (**Figure 1**); this is a multifilament synthetic suture which is absorbable and easier to handle and tie securely than monofilament sutures.

It is widely used to ligate small, subcutaneous vessels and in general surgery to ligate mesenteric vessels during bowel resections. For larger vessels (for example, the ileocolic artery) Vicryl can be used on a needle (rather than as a tie) to ensure adequate tissue is secured, to help reduce the risk of knot slipping. For control of bleeding following large calibre venous access removal, Vicryl has a superior time to haemostasis, ambulation and discharge as well as fewer complications compared with manual compression alone (Kumar et al, 2019). The ready availability and accessibility of suture materials and individuals competent to use them is one of the main benefits of suture control of bleeding. It is also cost effective when compared to other vessel sealing devices (Cheng et al, 2018). The main drawbacks are that it can be time consuming to perform, particularly intracorporeally, and there is a risk of technical failure.

Table 1. Comparison of common mechanical techniques

Method	Advantages	Disadvantages
Direct pressure	Easy, can achieve immediate short-term control	May not provide long-term control
Sutures	Versatile, many different varieties with differing properties, cheap	Risk of technical failure, may not be adequate for larger vessels
Clips	Easy to use, come in a range of sizes and materials	May become dislodged, risk of secondary thermal injury
Staplers	Quick and easy to use	More expensive, bleeding may result if wrong size used

Figure 1. Examples of polypropylene, polyglactin and silk sutures.

Clips

Clips are u-shaped metal or polymer devices which, using an applicator, can be flattened around a vessel or small tubular structure to occlude the lumen. Clips are used in both open and laparoscopic surgery; in the latter metal clips are made from titanium rather than stainless steel so they do not magnetise and become difficult to handle (Gould, 2011). Clips are comparable to other vessel ligation methods in vessels with diameters <5 mm and are easier to use intracorporeally than sutures (Rajbabu et al, 2007).

As clipping is a 'cold' method of haemostasis there is no risk of thermal damage to surrounding tissue when applying a clip device, but care must be taken to prevent subsequent injury when using energy devices nearby. However, clips can be dislodged from the vessel during further dissection or as a result of arterial pulsation; this risk is greater in larger vessels or if the clip is not applied at 90° to the vessel (Gould, 2011). The vessel also needs to be dissected away from surrounding structures to enable adequate margins and prevent collateral damage from the clip. In 1999, Hem-o-Lok clips (non-absorbable polymer clips with a locking mechanism) were introduced; these can be used to secure larger vessels and are better than staplers at preserving vessel length, which is beneficial during renal artery ligation for donor nephrectomy (Liu et al, 2018). Clips have also been modified for use during craniotomy surgery to maintain scalp haemostasis (Langford et al, 2009).

Staplers

Surgical staplers seal structures by compressing the tissue and delivering multiple rows of small staples (typically four or six) before dividing the tissue in the middle (Gould, 2011) (Figure 2). Staplers are commonly used on gastrointestinal tissue for bowel resection and/or anastomoses but this article focuses on the role of vascular staplers in sealing vessels and achieving haemostasis. When compared with clips and hand tied sutures, vascular staplers have similar performance under physiological conditions in vitro and vivo (Joseph et al, 2004; Liu et al, 2018). The main drawback for staple devices is the cost – a meta-analysis of renal pedicle ligation methods found that staplers cost on average $400 more than Hem-o-lok clips with no difference in clinical outcomes (Liu et al, 2018). Additionally, if the wrong size staples are selected, whether too short or too long, then there is a risk of bleeding as the staples will not interlock properly or will inadequately compress the tissue.

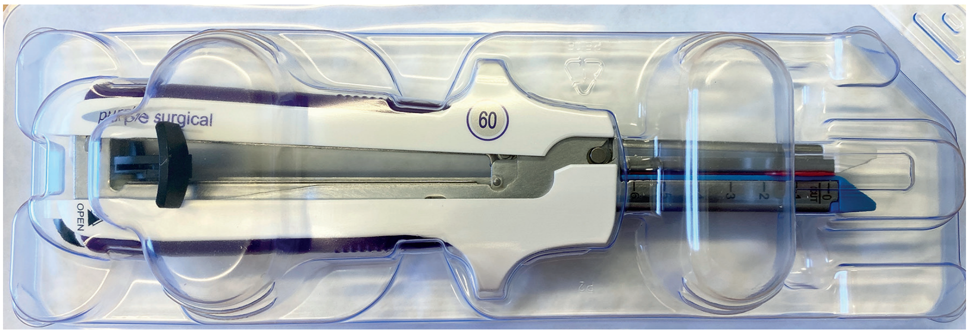

Figure 2. An example of a linear stapler.

Energy based

Electrosurgery

Electrosurgery relies on the principle of using high frequency electricity alternating at different currents to generate heat within tissues (El-Sayed et al, 2020). Differences in voltage allow for varied functions, such as cutting and coagulation (El-Sayed et al, 2020). By delivering a continuous waveform at a high power, the cutting function results in tissue vaporisation. This is in contrast to coagulation, which relies on a pulsed waveform that generates less heat and thus allows formation of a coagulum (Palanker et al, 2008). Electrosurgery can be further classified as either monopolar or bipolar depending on the method of delivery. In monopolar electrosurgery, the current is delivered via an active device and travels through the tissues to a return plate, which is usually placed on the patient's upper thigh or back. In contrast, bipolar electrosurgery has both the input and output confined to the instrument (El-Sayed et al, 2020). Electrosurgery technology has developed over the years and now encompasses electrothermal bipolar vessel-sealing devices; these devices combine pressure and electrical energy to seal vessels and have in-built sensors that alert the surgeon when the tissue is adequately sealed (Janssen et al, 2012).

Electrosurgery, in particular monopolar and bipolar devices, is used in all surgical specialties as a result of its widespread availability, versatility and lower cost compared with newer haemostatic devices (Sutton and Abbott, 2013). Bipolar vessel-sealing devices have superior sealing times and burst pressures when compared with ultrasonic devices (Lamberton et al, 2008) and comparable surgical outcomes to endoscopic staplers (Fathi et al, 2020). The main disadvantages of electrosurgery, particularly with monopolar devices, are thermal damage to surrounding tissues, inadvertent burns and interference with cardiac resynchronisation devices. The latter can occur as a result of stimulation of the atria, heat production and subsequent myocardial injury or in the case of implantable cardioverter-defibrillators, inadvertent activation (Apfelbaum et al, 2020). Thermal damage occurs as a result of transmission of energy beyond the intended structure and is increased by using monopolar devices, higher voltages, continuous currents and longer application times (El-Sayed et al, 2020). As a result of the risk of thermal damage, alternative haemostatic devices are preferred when in close proximity to delicate structures such as nerves and bowel. With regards to bipolar devices, care should be taken to avoid excessive tissue tension as this can result in avulsion before adequate haemostasis is achieved (Table 2).

Argon plasma coagulation

Argon plasma coagulation is a variant of monopolar electrosurgery that delivers 'non-contact' coagulation. Initially used in open hepatic surgery, it was later adapted for endoscopic surgery in the 1990s. The instrument emits a stream of argon gas that displaces the air around the target tissue. The device ionises the gas by passing an alternating current through it; once ionised the gas becomes argon plasma, which conducts the electrical current and causes coagulation in the tissue it is applied to (Zenker, 2008). As the tissue coagulates and desiccates, its impedance increases, shifting the focus of the plasma and limiting the depth of action to a few millimetres (Zenker, 2008). Consequently, collateral thermal

Table 2. Comparison of common energy-based techniques		
Method	**Advantages**	**Disadvantages**
Electrosurgery	Versatile, widely accessible, cheap	Risk of thermal injury
Argon plasma	Lower risk of thermal injury	May not control large vessels
Ultrasonic	Minimal risk of thermal injury, wide range of models	More expensive
Laser	Can deliver precise coagulation	Risk to operator if inappropriately used

Figure 3. An example of an ultrasonic sealing device.

damage from the device is minimised but this also means argon plasma coagulation devices cannot cut tissue or control bleeding from larger vessels. The main uses of argon plasma coagulation are superficial haemostasis and tissue ablation, particularly during endoscopic procedures, for example gastrointestinal endoscopy, hysteroscopy and cystoscopy. While argon is an inert gas, there are complications associated with its use: argon gas emboli have been reported in patients undergoing liver resections using argon plasma coagulation and when used during laparoscopic surgery the stream of argon gas can further increase intra-abdominal pressure (Gould, 2011).

Ultrasonic devices

Ultrasonic devices work by using vibration to both cut and cauterise tissue (Figure 3). Using high frequencies (in the region of 55 000 Hz) these devices generate friction between molecules, resulting in heat production and protein denaturation (Fitzgerald et al, 2012). With most being able to seal vessels up to 7 mm, they are frequently used during colonic mobilisation to minimise small vessel bleeding. In addition, given there is minimal damage to surrounding tissue (Dutta and Dutta, 2016), these devices are frequently used to minimise blood loss during thyroid surgery where careful protection of surrounding nerves is essential (Foreman et al, 2009). Newer devices incorporate both ultrasonic and bipolar principles to seal vessels although there appears to be no difference in outcome when compared with standard ultrasonic devices (Suhardja et al, 2018). One of the main disadvantages is the cost of the device at the point of use. However, a meta-analysis has shown that this is offset by reduced operating times and so their use overall reduces costs in a range of different procedures (Cheng et al, 2018).

Lasers

Lasers are devices that produce a powerful narrow beam of electromagnetic radiation in a single wavelength; depending on the wavelength and pulse duration, lasers can be used to cut, coagulate or ablate tissue (Gould, 2011). The name laser is an acronym for the method by which the wavelength is produced – ‘light amplification by stimulated emission of radiation’. The device consists of an external energy source that excites the atoms in the laser medium; these atoms, when they return to their low-energy state, emit photons that are reflected within the resonance chamber to produce an electromagnetic beam with a specific wavelength (Colt, 2011). Laser wavelength is selected according to the target molecule, for example oxyhaemoglobin, which absorbs the light and then dissipates the energy as thermal or chemical energy (Colt, 2011). The versatility of lasers means they are used in a range of medical and surgical specialties, most commonly in ophthalmology and dermatology. Lasers can also be delivered via fibreoptic cables making them useful in endoscopic and laparoscopic procedures. Unlike other methods of haemostasis discussed here, lasers provide very precise coagulation; the CO_2 lasers used in otorhinolaryngology can seal blood vessels up to 0.5 mm diameter (Betka et al, 2013). Laser radiation can damage the eyes and skin of users and patients so appropriate training and safety equipment is required for theatre staff and surgeons (Samudrala, 2008; Colt, 2011).

Topical agents

If, as a result of the location or the presence of friable tissue, haemostasis cannot be achieved using other methods, then topical agents can be used. Topical agents are classified as passive, promoting platelet aggregation but reliant on an intact coagulation cascade, or active, containing fibrinogen and/or thrombin and triggering clot formation (Samudrala, 2008; Huang et al, 2020). As many topical agents are derived from biological sources (human, shellfish, bovine or equine), there is a risk of immune reaction and it is important to consider any patient allergies. In clinical practice, fibrin sealants have a higher success rate of haemostasis compared with conventional methods in patients undergoing aortic aneurysm surgery (Weltert et al, 2016). While traditionally used for wound management, in vitro studies have shown that alginate dressings may also have haemostatic properties (Rembe et al, 2015). Passive agents can absorb large volumes of blood and swell, so caution should be exercised when using them in enclosed spaces to prevent compression of neurovascular structures (Samudrala, 2008; Huang et al, 2020).

Conclusions

Techniques for maintaining intraoperative haemostasis are varied and encompass many different principles. Although they all have broadly similar effectiveness, each has unique properties that make them preferred for particular operations. Undoubtedly surgeon preference will also influence which methods are used. It is important for those involved in the operating environment to be aware of the potential drawbacks of each to reduce and prevent negative outcomes.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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Key points

- Intraoperative blood loss is associated with worse patient outcomes and increased costs of care.
- Mechanical techniques to prevent bleeding (such as pressure, suture ligation, clips, staplers) are cost effective although there is a risk of technical failure.
- Energy-based devices are most commonly used because of their versatility, but care should be taken to prevent damage to surrounding tissue.
- Topical agents are useful for friable tissues but carry a risk of immune reactions.
- Patient and procedural factors, as well as the surgeon's preference, need to be considered when choosing a haemostatic technique.

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