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REVIEW OPEN ACCESS

Topical hemostatic agents in surgical hemostasis: A review

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Abstract

Rapid, effective hemostasis using biocompatible, user-friendly agents is essential to reduce bleeding-related perioperative morbidity and preventable mortality. This review aimed to evaluate the clinical use and effectiveness of topical hemostatic agents across gastrointestinal bleeding, minimally invasive, reconstructive gynaecologic surgery and obstetrics, orthopedic related surgeries, and emergency medicine. Gastrointestinal studies report excellent immediate control but variable 7-30-day re-bleeding. Gynaecologic and obstetric applications show reduced intraoperative blood loss and preserved tissue function. Orthopedic data demonstrates reduced transfusion and perioperative blood loss. Emergency and trauma evidence support rapid control with kaolin/chitosan and emerging self-gelling powders. Advanced hemostatic agents particularly next-generation powders provide high immediate efficacy, but outcome variability highlights the need for larger comparative studies. Emerging biomaterials show strong promise, underscoring the importance of continued innovation to achieve durable, tailored hemostasis across diverse clinical settings.

Keywords: hemostatic agents; gastrointestinal bleeding; gynecologic surgeries; orthopedic surgeries; emergency medicine

Introduction

Bleeding associated with gastrointestinal bleeding, minimally invasive, reconstructive gynaecologic surgery and obstetrics, arthroplasty, spine surgery, and trauma-related bleeding, emergency medicine remains a major global health challenge, accounting for substantial perioperative morbidity and preventable mortality worldwide. Rapid and effective hemostasis is essential, and recent advances in biocompatible, easy-to-use hemostatic agents have significantly enhanced bleeding control across multiple clinical settings [1, 2]. Modern hemostatic materials function by either accelerating the natural coagulation cascade or directly supporting clot formation through mechanical, chemical, or biological mechanisms [1, 3].

Hemostatic agents are broadly classified into topical and systemic categories based on their route of administration and clinical application. Table 1, summarizes the major types used in medical practice. Topical agents include mechanical hemostats such as gelatin, collagen, oxidized regenerated cellulose, and polysaccharide powders that support passive clot formation. Active hemostats incorporate thrombin-based components to accelerate coagulation, while sealants and adhesives such as fibrin formulations, synthetic polymers, and peptide hydrogels provide effective tissue sealing. Hemostatic powders and dressings, including kaolin, chitosan, and mineral-based agents, offer rapid bleeding control. Systemic agents include antifibrinolytics, coagulation factor replacements, and platelet function enhancers, each acting through distinct mechanisms to optimize hemostasis.

Topical hemostatic agents are widely used when suturing, electro cautery, or direct pressure fail, as they provide structural scaffolds, concentrate clotting factors, form adhesive barriers, or deliver active biological components such as thrombin or fibrin to enhance clot formation [2-4]. These materials include passive mechanical matrices (gelatin, cellulose), biologic sealants, flowable formulations, polysaccharide-based powders, and advanced biomaterial composites such as chitosan dressings and hydrogels, which demonstrate high efficacy in both surgical and emergency

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settings [5-8]. Systemic hemostatic agents, including antifibrinolytics and coagulation factor concentrates, remain essential in massive trauma, coagulopathies, and uncontrolled hemorrhage where systemic correction of clotting pathways is required [1, 9].

Table 1: Classification of Hemostatic Agents.

Classification category	*Sub-category*	*Main ingredient(s)*	*Examples of agents & products*
Topical hemostatic agents	Mechanical/Passive hemostats	Porcine/bovine gelatin; bovine collagen; oxidized regenerated cellulose (ORC); polysaccharide spheres (starch)	Gelatin-based:Gelfoam, Surgifoam; Collagen-based:Avitene, Ultafoam; ORC: Surgicel, Oxycel; Polysaccharide spheres: Arista AH, PerClot, EndoClot PHS
	Active hemostats	Thrombin (bovine, human, or recombinant); gelatin matrix + thrombin	Thrombin:Thrombin-JMI, Evithrom, Recothrom; Flowable Hemostats: Floseal, Surgiflo
	Sealants and adhesives	Fibrinogen + Thrombin; polyethylene glycol; albumin/glutaraldehyde; self-assembling peptides (RADA16)	Fibrin sealants: Tisseel, Evicel; Synthetic sealants: COSEAL, DuraSeal; Albumin/Glutaraldehyde: BioGlue; Peptide hydrogel: PuraStat, PuraBond
	Hemostatic powders/ Dressings	Kaolin; chitosan; bentonite (mineral powder) and plant extracts	Kaolin-based: QuikClot Combat Gauze; Chitosan-based: Celox, HemCon Bandage Mineral Powder: Hemospray (TC-325); Herbal Extract:Ankaferd Blood Stopper (ABS)
Systemic hemostatic agents	Caustic agents	Aluminum Chloride, Ferric Sulfate	ViscoStat, Monsel's solution
	Antifibrinolytics	Tranexamic acid (TXA); Aminocaproic acid	Cyklokapron
	Coagulation factor replacements	Factor VIII, Factor IX, etc; Recombinant Factor VIIa; Vitamin K	Factor concentrates for hemophilia: NovoSeven RT, Mephyton
	Platelet function enhancers	Desmopressin acetate (DDAVP)	Stimate, DDAVP

Advances in polysaccharide-derived biomaterials, military/battlefield hemostatic systems, and next-generation regenerative wound interfaces are steadily enhancing the performance and applicability of hemostatic agents across gastro-intestinal bleeding, minimally invasive, reconstructive gynaecology surgeries and obstetrics, orthopedic surgeries such as arthroplasty, spine surgery, trauma-related bleeding and emergency medicine [6-8, 10, 11]. Given the diversity of bleeding types, anatomic sites, and departmental clinical practices, a comprehensive multi-department evaluation is vital to understand real-world use patterns, effectiveness, and safety of existing hemostatic options.

The objective of this study was to evaluate the use and effectiveness of various hemostatic agents employed in surgical and procedural practice across gastro-intestinal bleeding, minimally invasive, reconstructive gynaecology surgeries and obstetrics, orthopedic surgeries such as arthroplasty, spine surgery, trauma-related bleeding and emergency medicine.

Gastrointestinal bleeding

Gastrointestinal bleeding (GIB) is a common cause of emergency hospitalization and is associated with high morbidity and mortality. The major etiologies include non-variceal, variceal, post-endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), and tumor-related bleeding. Conventional endoscopic methods such as thermal coagulation, injection therapy, and hemoclips is limited in diffuse or difficult-to-access sites [12–15].

Topical hemostatic powders have emerged as effective adjuncts in endoscopic management. Hemospray (TC-325) provides rapid, contactless hemostasis and has been used successfully for non-variceal, variceal, and malignancy-related bleeding [12,18,20,23]. Controlled trails and clinical studies indicate that topical hemostatic powders, particularly Hemospray (TC-325), achieve immediate hemostasis in approximately 80–98% of cases, with slightly higher rates reported in non-variceal upper GI bleeding (~85–95%) and lower rates in more complex or malignancy-related lesions (~80–85%) [18–20]. EndoClot, a polysaccharide-based powder, absorbs water from blood to form a mechanical tamponade, and NexPowder offers enhanced adhesive properties; both are particularly useful for post-EMR/ ESD lesions and friable tumor surfaces [13,17,21].

These powders can be applied as monotherapy or in combination with conventional endoscopic techniques when diffuse oozing limits other methods [19,22].

Overall, hemostatic powders provide rapid, non-contact control across diverse GIB scenarios. They reduce the need for rescue interventions, prevent delayed bleeding after EMR/ESD, and offer a safe and effective option for managing high-risk or malignant lesions. Among available agents, Hemospray remains the most versatile, while EndoClot and NexPowder are valuable for protecting resection sites and tumor-related bleeding [12–23]. Collectively, these powders provide a safe, rapid, and effective means of achieving hemostasis, reinforcing their growing role in modern endoscopic practice (Table 2).

Minimally invasive, reconstructive gynaecologic surgeries and obstetrics

Bleeding during gynaecologic and obstetric procedures remains a major cause of maternal morbidity, particularly during caesarean sections, and fertility-preserving reconstructive operations. In these settings, effective hemostasis must be achieved quickly without causing tissue damage or compromising future fertility. Traditional methods such as suturing or electrocautery is limited when bleeding is widespread, persistent, or located in deep wound areas. As a result, topical hemostatic agents are increasingly used as adjuncts to conventional surgical techniques [24].

Several classes of topical hemostatic agents are currently employed in gynaecologic and obstetric practice, including flowable gelatin-thrombin matrices, fibrin sealants, chitosan-based products, polysaccharide powders, and self-assembling peptide systems. These agents act locally, allowing precise bleeding control while minimizing thermal or mechanical injury to surrounding tissues [24–26].

In minimally invasive gynaecologic surgeries such as laparoscopic hysterectomy and myomectomy, flowable matrices and fibrin sealants have shown success in reducing postoperative blood loss, perioperative transfusions and operative time [26]. In obstetric care, topical agents have shown benefit in managing postpartum hemorrhage by reducing blood loss and decreasing the need for invasive interventions, including emergency hysterectomy [25]. During complex procedures involving dense adhesions, topical hemostats help control diffuse oozing and support safer tissue separation [26]. In gynaecologic oncology and cervical procedures, where tissues are highly vascular, non-contact powders and peptide-based agents provide rapid bleeding control [27].

Overall, topical hemostatic agents have demonstrated high clinical effectiveness, with reported hemostasis success rates of approximately 85–95% in gynaecologic and obstetric settings [24–26]. Flowable and sealant-based agents are well suited for localized bleeding, while powders and peptide systems are particularly useful for diffuse or minimally accessible bleeding sites [26,27] (Table 2). Their integration into routine practice has improved surgical safety, reduced transfusion requirements, and supported fertility-preserving approaches in modern gynaecologic and obstetric care.

Arthroplasty, spine surgery, and trauma-related bleeding

Orthopedic procedures are frequently associated with significant blood loss due to extensive soft-tissue dissection and exposure of cancellous bone. Surgeries such as total hip and knee arthroplasty, spine surgery, fracture fixation, and trauma reconstruction require reliable hemostatic strategies to limit perioperative blood loss and reduce transfusion rates [28]. Standard techniques, including suturing, electrocautery, and bone wax, may be insufficient in cases of diffuse bleeding, prolonged operative time, or in elderly patients with comorbidities. As a result, topical hemostatic agents and pharmacologic adjuncts are widely incorporated into orthopedic practice [28–31].

A variety of hemostatic agents are currently used depending on the bleeding source and surgical setting. Topical tranexamic acid (TXA) is one of the most extensively studied agents in orthopedic surgery and has demonstrated consistent efficacy in reducing blood loss and transfusion requirements in total hip and knee arthroplasty, femoral fracture surgery, and spine procedures [30,31,33,34,36]. Oxidized regenerated cellulose products, such as Surgi-ORC®, provide a physical matrix for clot formation and have shown favorable safety and effectiveness in real-world orthopedic settings [29]. Fibrin sealants are commonly applied to soft-tissue surfaces during joint replacement surgery, where they reduce drainage volume and transfusion needs [32].

Collagen-based hemostats, including microfibrillar collagen formulations, support platelet aggregation and clot stabilization and are frequently used as adjuncts in orthopedic and trauma surgeries [35]. In spinal procedures, topical TXA and flowable agents are particularly useful for controlling diffuse epidural and paraspinal bleeding, where mechanical methods alone are often inadequate [34,36].

Overall, modern hemostatic agents particularly topical tranexamic acid, fibrin sealants, oxidized regenerated cellulose (Surgi-ORC®), and collagen-based hemostats demonstrate strong clinical performance across orthopedic procedures, with consistent reductions in blood loss and transfusion rates and reported efficacy ranging from approximately 80-95% [28-32] (Table 2). Their targeted application has improved intraoperative bleeding control, shortened operative time, and enhanced patient outcomes in arthroplasty, spine surgery, and trauma care.

Emergency medicine

Uncontrolled hemorrhage is one of the leading causes of preventable death in trauma and emergency care. Rapid bleeding control is essential to prevent hypovolemic shock and improve early survival, particularly in patients with severe injuries or trauma-induced coagulopathy [37].

Topical hemostatic agents play an important role in trauma management, especially in pre-hospital and emergency surgical settings. According to a systematic review by Chiara et al. [37], agents such as chitosan-based dressings and polysaccharide hemostatic powders are widely used to control external bleeding from extremity and junctional wounds. These agents act locally by absorbing blood and forming a physical barrier, allowing bleeding control even when normal coagulation pathways are impaired. Their ease of application and rapid action make them suitable for uncontrolled and time-critical emergency environments [37].

During emergency surgery and damage-control procedures, topical hemostatic agents are used to manage diffuse bleeding and stabilize the operative field until definitive surgical repair can be performed. The systematic review in [37] highlights the value of topical hemostats in trauma surgery, particularly in situations where conventional techniques alone are insufficient. These agents help reduce ongoing blood loss and support temporary hemostasis in complex wound settings.

Recent material-based advances have further improved emergency hemostasis. Li et al. [38] reported the development of a self-gelling polymer-based powder that rapidly forms a stable gel upon contact with blood, providing effective bleeding control along with antibacterial properties. This self-gelling behaviour allows strong adhesion to irregular wound surfaces and supports rapid hemostasis in experimental and emergency-relevant conditions [38] (Table 2).

Overall, evidence from trauma-focused studies demonstrates that topical hemostatic agents, including chitosan dressings, polysaccharide powders, and self-gelling polymer systems, provide effective and rapid bleeding control in emergency medicine.

Table 2: Hemostatic agents, their applications, and clinical effectiveness in Gastrointestinal Bleeding, Minimally Invasive, Reconstructive Gynaecologic Surgery and Obstetrics, Arthroplasty, Spine Surgery, and Trauma-Related Bleeding, and Emergency Medicine.

Category	*Hemostatic agent*	*Application / Procedure*	*Reported hemostasis rate*
Gastrointestinal bleeding	Hemospray (TC-325) [12,14,19]	Non-variceal upper GI bleeding: Acute bleeding from peptic ulcers or diffuse oozing	~85-95%
	Hemospray (TC-325) [13,20]	Variceal bleeding (rescue)	~80–90%
	Hemospray (TC-325) [15,18,23]	Malignancy-related upper GI bleeding	80–98%
	EndoClot [16,21,22]	Post-ESD / EMR bleeding	82–90%
	NexPowder [17,21]	Post-EMR / ESD bleeding: Tumor or post-resection sites	85–92%
	NexPowder [20]	Lower GI bleeding	~85%
Minimally invasive, reconstructive gynaecologic surgery and obstetrics	Flowable gelatin-thrombin matrix [24,26]	Laparoscopic hysterectomy / myomectomy	~85–95%
	Fibrin sealant [24,26]	Laparoscopic hysterectomy / myomectomy	~85–95%
	Chitosan-based products and polysaccharide powders [25]	Postpartum hemorrhage / obstetric surgery	~85–90%
	Self-assembling peptide [27]	Rapid control of bleeding in highly vascular during gynaecologic oncology and cervical procedures	~90%

Arthroplasty, spine surgery, and trauma-related bleeding	Fibrin sealant [32]	Total hip/knee arthroplasty	~85–90%
	Topical tranexamic acid (TXA) [30,31,33]	Total hip/knee arthroplasty	~80–95%
	Oxidized regenerated cellulose (Surgi-ORC®) [29]	Arthroplasty and fracture fixation	~85–90%
	Topical TXA and flowable gelatin-thrombin matrices [34,36]	Paraspinal bleeding during spine surgery	~80–90%
	Collagen-based hemostats (microfibrillar collagen) [35]	Orthopedic trauma and fracture surgeries	~85–90%
Emergency medicine	Chitosan-based dressing [37]	Extreme bleeding and pre-hospital care	~80–90%
	Polysaccharide powder [37]	Pre-hospital care for open wounds	>80%
	Self-gelling polymer-based powder (polyacrylic acid/PEI/PEG) [38]	Emergency bleeding for irregularly shaped wounds during surgeries and pre-hospital trauma	>90%

Future directions

Despite substantial advances in hemostatic agents, important evidence gaps remain. Future research should emphasize large, multicenter randomized controlled trials comparing different topical hemostatic classes across gastrointestinal, gynaecologic, orthopedic, and emergency settings, using standardized outcomes such as durability of hemostasis, re-bleeding, transfusion needs, and safety. Innovation should focus on next-generation, fully resorbable biomaterials effective in complex bleeding environments. Integration into minimally invasive and image-guided procedures, evaluation of combination strategies, and robust real-world and cost-effectiveness data are also needed to support personalized, guideline-driven hemostatic decision-making.

Conclusion

This review highlights the expanding role of modern hemostatic agents such as flowable matrices, fibrin sealants, chitosan-based dressings, polysaccharide-based powders, chitosan dressings, topical tranexamic acid, emerging self-assembling or self-gelling biomaterials and next-generation hemostatic powders in achieving rapid and effective bleeding control across gastrointestinal, gynaecologic, orthopedic, and emergency settings. These agents are particularly valuable in diffuse, inaccessible, or refractory bleeding where conventional techniques are limited or inadequate. Clinical evidence consistently supports high rates of immediate hemostasis, generally ranging from 80–95%, with meaningful reductions in transfusion requirements, operative time, and procedural complications across multiple specialties. However, variability in outcomes and re-bleeding rates indicates the need for standardized evidence and long-term clinical data. Advances in biomaterial science and delivery technologies are expected to further refine hemostatic practice, enabling safer, more effective, and more tailored bleeding management strategies. With continued innovation, robust clinical evaluation, and integration into evidence-based guidelines, hemostatic agents are poised to remain indispensable tools in modern surgical and emergency care.

Conflict of interest

Authors declare no conflict of interest.

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