The Egyptian Journal of Hospital Medicine (January 2023) Vol. 90, Page 335-342

The Role of Absorbable Gelatin Sponge (Gel Foam) in Control of Sternal Bleeding during Cardiac Surgery

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ABSTRACT

Background: Topical hemostatic agents based on gelatin have been shown to be successful in stopping bleeding throughout open heart surgery, in conjunction with traditional methods.

Objective: To study the efficacy of gel foam for controlling postoperative bleeding in cardiac surgery.

Patients and Methods*:* A prospective randomized study was performed in Cardiac Surgery Unit of Elkasr Elaini Medical Center, Cardiovascular Surgery Department in Cairo University, Cairo, Egypt. A total of 120 cases went through heart surgeries were allocated in 2 groups, 60 cases in each. In group A, gel foam wasn't used but used in group B under sternum on closure. Study endpoints were the rate of total blood drainage, reopening for bleeding, use of blood products, tamponade and mediastinitis.

Results: Statistically higher rates of reopening for bleeding, total blood drainage, blood transfusion and tamponade in group A comparing to group B, (p=0.015, < 0.009, <0.001 and 0.006 respectively). Rate of mediastinitis did not statistically vary between both groups, but were lower in group B.

Conclusion: Gel foam is effective in reducing postoperative hemorrhage in conjunction with traditional surgical procedures. Its thoughtful use is linked to lower rate of reopening for bleeding after cardiac surgery.

Keywords: Gel foam, Hemostatic agent, Cardiac surgery, Sternal bleeding.

INTRODUCTION

Cardiac surgical procedure is closely correlated with perioperative hemorrhage and a serious potential of transfusion. Hemorrhagic complications in open heart surgery are linked to worse consequences and play a role to elevated total healthcare expenditure [(1)]. The estimated incidence of all unselected patients undergoing cardiac surgery is 5-9%, with limit values ranging from 0-16%[(2)]. The requirement for intraoperative and postoperative blood transfusions is also linked to possible risks such as bad effects, transfusion-related harm, or pathogenic transmissions, all of which are considerable morbidity or death attributes[(1)]. Hemorrhage occurs as a consequence of many components and steps in cardiac surgery, including the placing of cardiovascular incision lines in large vessels or cardiac chambers and the formation of high-pressure anastomoses. Stainless steel wire used in sternal closure is responsible for more than 20% of causes of reopening [(3)].

Massive microvascular hemorrhage upon heart surgery can lead to re-exploration, which has been linked to a number of adverse consequences, including a three to four folds increase in operating room period, blood and blood components transfusions, pulmonary hypertension, renal failure, sepsis, atrial arrhythmias, long-lasting mechanical ventilation, extending duration of stay, and causing death [(4)]. Blood loss also impairs visualization of the operational area and extends operational processes [(5)]. Excessive hemorrhage could cause acidosis and hypothermia which could cause coagulopathy (lethal triad) [(6)].

Blood products are used in approximately 21% of all operational processes and 45.8% of cardiovascular instances, but they are linked to a variety of complications and risks. Transfusions is also linked to immunomodulation, bacterial infections and a lot of non-infectious but significant health problems [(7)].

Systemic and local methods should be used to achieve hemostasis. The systemic treatment by blood transfusions and pro-coagulant medication is critical, but it additionally carries significant potentials. Systemic medications, like anti-fibrinolytics and recombinant Factor VII, are commonly prescribed to treat coagulation defects, but they are costly. Most cardiac procedures do not have sufficient proof to support the administration of recombinant Factor VII[(8)].

Traditional strategies, such as suture applications and vessel ligation, or electrocautery, were the initial local strategies of direct postoperative control of suture lines, anastomosis, and other topics of the operative area. There are numerous hemostatic manoeuvres, ranging from simple digital pressure management, electrical tissue cauterization and wound irrigation with warm saline to topical administration of pro-coagulant substances [(9)] **(Figure 1).**

Received: 20/08/2022
Accepted: 21/10/2022

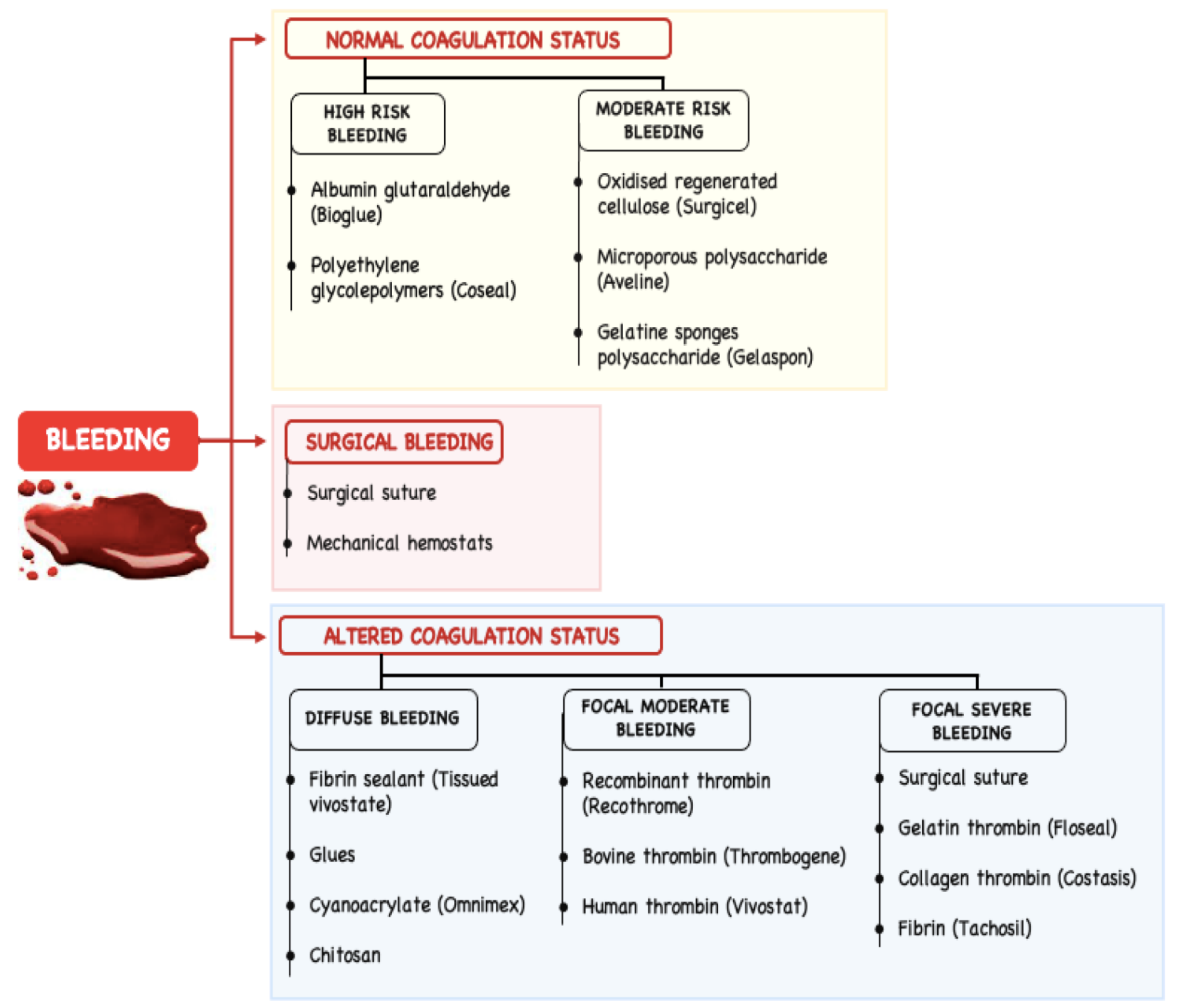

Figure (1): Bleeding management using hemostatic agents [10].

Those new therapeutic supplements developed over centuries are efficient in achieving coagulation cascade during heart operations. Local gelatins, collagens, oxidized celluloses, thrombin and fibrin sealants, synthetic glues, and glutaraldehyde-based glues are some examples. The efficient utilization of local treatments is heavily reliant on the surgeon's observation or favorite, as well as their affordability in the surgery room [10].

Topical agents have potentials as well, and their effectiveness has not been thoroughly assessed in big randomized, placebo-controlled prospective trials. Because of the comparatively modern development of minimally invasive techniques in cardiac surgery, these innovative additives are being utilized more frequently to accomplish hemostasis where traditional suturing techniques has proven to be challenging [9] **(Table 1)**.

Table (1): Categorization of marketable hemostatic components according to active agents [10].

Commercial Hemostatic Agents	Commercial name	Specifications/Composition
I. Without Human or Bovine Component	Surgicel	Oxidized cellulose polymer
	Oxycel	
	Omnex	Synthetic tissue adhesive (Cyanoacrylates)
	Coseal	Combination of two polyethylene glycol polymers
	Arista	Microporous polysaccharide hemispheres
	Hem Con	Freeze-dried chitosan derived from shrimp shell contains chitosan
	ChitoSeal	
	Celox	
	Recothrom	Recombinant thrombin (topical use)
	Gelfoam	Absorbable gelatin sponges
II. With Bovine Component	BioGlue	Bovine albumin, and glutaraldehyde
	CoStasis	Bovine collagen, bovine thrombin, and calcium chloride mixed with autologous plasma at the time of surgery
	Thrombin	Bovine protein
	Avitene	Water-insoluble acid salts of bovine collagen
	Colgel	
	Helitene	
III. With Human Plasma Component	Tisseel	Human thrombin and fibrinogen, synthetic aprotinin
	Vivostat	Combination of platelets and autologous fibrin (prepare on site)
	Crosseal	Tranexamic acid, human plasma protein, thrombin
	Quixil	
IV. With Bovine and Human Plasma Component	Floseal	Human thrombin and bovine gelatin
	Beriplast	Human thrombin and fibrinogen, bovine aprotinin

Using simple sutures, pledged sutures, squeezing with cottoned cutlets, electrocautery, or the application of vascular elastic bands and clips, hemorrhage from heart or vessel structures can be simply manipulated [7]. Warm saline flushing or the application of local hemostatic supplement may be required in the case of diffuse capillary blood loss. Bone wax, which is composed of bees' wax and paraffin or Vaseline, is frequently applied to control the hemorrhage from the sternum by mechanically blocking the bone's spongiosa. On the other side, it can result in adverse reactions such as osteomyelitis, granuloma, or poor sternum ability to heal [11].

In addition, there are new hemostatic substances that give its effect without depending on coagulation mechanisms [12]. These substances present extrinsic clotting factors when applied and imitates numerous phases of the coagulation process. The main applicants of this class involve thrombin sealants (Thrombin, Thrombogen, and Thrombostat), fibrin sealants (Tisseel), fibrin patches (TachoSil, and TachoComb), autologous fibrin and thrombocytes concentrates (Vivostat) and gelatin–thrombin matrix sealant (Floseal).

Furthermore, non-active substances, which do not hold coagulation characteristics; they involve physical hemostatic assistants and synthetic sealants. Traditional local hemostatic agents form physical lattices that promote clot creation [11]. Gelatin sponges as gel foam (Baxter, Hayward, CA, USA), gelaspon [13], microfibrillar collagens as avitene flour MCH (Davcol, Warwick, RI, USA), colgel, and helitene [11], oxidized regenerated cellulose as surgicel (Ethicon, Somerville), microporous polysaccharide hemispheres as arista (Medafor, Minneapolis, MN, USA) [14].

These applicants have shown differential effectiveness, and their administration is frequently hampered by application difficulty, particularly over excessive hemorrhagic locations or difficult-to-reach sites, as well as a failure to be effective when applied to heparinized patients [11].

Future research should concentrate on the discovery of novel bioactive substances, the modularization of hemostatic simulation, and the improvement of methods in multiple biomaterials and technologies to encourage and enhance effective platelet activation in hemorrhagic locations.

The purpose of this prospective research was to evaluate use of absorbable gelatin sponges (gel foam) and its impact on sternal ooze after stainless steel wire insertion in cardiac surgical operations, in comparison to an untreated control individuals, and to examine the endpoints including the rate of total blood drainage, reopening for bleeding, blood products transfusion, cardiac tamponade and mediastinitis.

PATIENTS AND METHODS

A prospective randomized study was performed in Cardiac Surgery Unit of Elkasr Elaini Medical Center, Cardiothoracic Surgery Department in Cairo University, Cairo, Egypt. A total of 120 cases in the period from January 2017 to January 2019 underwent heart surgery were allocated into two groups 60 individuals in each; in group A we didn't use gel foam and group B we used gel foam under sternum on closure.

Ethical approval:

The approval of our study was attained from Cairo University Academic and Ethical Committee. A written informed consent forms were signed and completed by each participant in the study. The study was conducted according to the Declaration of Helsinki.

Inclusion criteria:

We included patients who underwent coronary artery bypass grafting surgery (CABG) or valve replacement surgery through median sternotomy. Enrollment in both groups for patients who had excessive sternal bleeding after wire insertion.

Exclusion criteria:

Patients were excluded if they underwent a minimal invasive procedures through right or left mini-thoracotomies, redo operation, rewiring and had mediastinitis or infective endocarditis.

Study treatments and data collection:

In only 24 hours of the operating condition, an initial blood sample was taken to assess the full blood count, blood cell disparities, partial thromboplastin activated period, prothrombin period, and metabolic, hepatic, and renal panels. Besides, routine echo duplex ECG and chest X-ray was implied to all patients preoperatively.

Study endpoints were the rate of: total blood drainage, reopening for bleeding, blood product transfusion, tamponade and mediastinitis.

Surgical technique:

In both groups A and B standard anesthesia and surgical procedures were used and median sternotomy was applied in all cases to expose the heart. In cases of CABG and valve replacement, heparin was administered with dose of 3 mg/kg before the establishment of cardiopulmonary bypass (CPB). During it, activated clotting time was controlled at > 400 seconds.

In total number of individuals, ascending aortic cannulation was performed and in valve replacement superior and inferior vena cava cannulae were applied. While a two-phase intravenous cannulation of the right atrium was applied in cases who underwent CABG. In the ascending aorta, a cardioplegia delivery cannula with an independent vent connection (DLP Medtronic, Grand Rapids, MI, USA) was implanted. A Dideco D704 compressed system oxygenator (Dideco, Mirandola, Italy) and a Stöckert S3 roller pump (Stöckert, Munich, Germany) were used in the extracorporeal circuit. To preserve a mean arterial pressure of 60-70 mmHg, the pump run frequency was maintained from 2.0 to 2.4 l/min per m^2 body surface area.

In CABG patients, intermittent antegrade infusion of warm blood cardioplegic potassium solution every 20 minutes was used. In valve replacement procedures cold cardioplegic solution was given in the aortic root or directly into coronary ostia if there was aortic regurge.

After weaning from bypass and removal of arterial and venous cannulae, hemostasis was done routinely in both groups A and B using electric cautery, metallic clips and ligature sutures securing at surgical lines. After inserting two mediastinal chest tubes and one left pleural tube sternum was closed using four figures of eight stainless steel wires.

In group A, sternal bleeding was controlled using cautery and compression with gauzes, in addition to sutures. In group B sternal bleeding was controlled by cautery and compression, sutures in addition to 2 gel foam patches inserted longitudinally (Figure 2) between the inner table of both sternal edges and the stainless-steel wires in order to tamponade any bleeding source from the site of wire entry. Closure of muscles and subcutaneous tissue was done using Vicryl 2 sutures and skin was closed using Monocryl 3/ 0 sutures in both groups A and B.

Figure (2): A and B controlling sternal bleeding using gel foam patches. C and D gel foam patches.

Statistical analysis

Statistical analysis was performed using the SPSS® statistical package, version 10.1 (SPSS Inc., Chicago, IL, USA) for Windows®. Numerical variables were presented as means ± SD and were compared using the Student's t-test or the Mann-Whitney U-test, while non-numerical variables were presented as number and percentage and were compared using Fisher's exact test. A P-value of 0.05 was deemed statistically significant.

RESULTS

A prospective study was conducted in Cardiac Surgery Unit of Elkasr Elaini Medical Center Cardiovascular Surgery Department in Cairo University, Cairo, Egypt. A total of 120 cases underwent cardiac surgery were allocated into two classes, each consisted of 60 patients, regarding the use of gel foam as hemostatic agent during cardiac surgery.

Descriptive statistics:

The demographic and preoperative features of cases in the two groups are illustrated in table 1, which didn't show any significant difference between the two groups regarding age, sex or co-morbidities.

Most of the participants were males with more than 50 years old. About half of the participants were diabetic and hypertensive.

Table (1): Demographic and pre-surgical features of cases went through cardiac surgery

		Group A	Group B
Age		54±6	55±7
Sex	**Male**	54(45)	58(48.3)
	Female	6(5)	2(1.7)
Diabetic	**No**	27(22.5)	25(20.8)
	Yes	33(27.5)	35(29.2)
HTN	**No**	22(18.3)	29(24.2)
	Yes	38(31.7)	31(25.8)
Coagulation abnormality	**No**	55(91.7)	59(98.3)
	Yes	5(8.3)	1(1.7)

(Data are *n*, *n* (%) or mean ± SD.)

Comparative statistics:

Intra-surgical features and post-surgical clinical consequences of cases are showed in tables 2 and 3.

In table 2, coronary artery bypass grafting surgery (CABG) was significantly higher in the two groups than valve replacement.

Table (2): Comparison of types of surgery between both groups

	Group A	Group B
Valve replacement	9 (17.6%)	11 (18.3%)
CABG	51(82.6%)	49 (81.7%)

Table 3 demonstrated statistically significant difference in the total blood drainage where its median was lesser in group B.

Table (3): Comparison of the 2 groups regarding total blood drainage

	Groups				
	A		B		P value
	Median	IQR	Median	IQR	
Total drainage	820	550	690	219	0.009

Table 4 showed the number of blood components mean that was used in each patient. They were administrated for group B significantly lower than group A.

Table (4): Comparison of the number of used blood components in each patient between the 2 groups

Groups	N	Mean	Std. Deviation	Std. Error Mean	p value
A	60	3.48	1.255	0.162	<0.001
B	60	1.52	0.792	0.102	

In tables 5 and 6, there was statistically significant higher rate of post-surgical exploration and cardiac tamponade in group A than group B (p< 0.001).

Table (5): Comparison of the 2 groups regarding exploration

		Group		Total	P value
		A	B		
Exploration	No	50	58	108	
		46.3%	53.7%	100.0%	0.015
	Yes	10	2	12	
		83.3%	16.7%	100.0%	

Table (6): Comparison of the 2 groups regarding tamponade

		Group		Total	P value
		A	B		
Tamponade	No	53	60	113	0.006
		46.9%	53.1%	100.0%	
	Yes	7	0	0	
		100.0%	0.0%	100.0%	

Also, there was no statistically significance difference in mediastinitis between both groups (Table 7).

Table (7): Comparison of the 2 groups regarding mediastinitis

		Groups		Total	P value
		A	B		
Mediastinitis	No	58	59	117	0.559
		49.6%	50.4%	100.0%	
	Yes	2	1	3	
		66.7 %	33.33 %	100.0 %	

DISCUSSION

A common heart surgery complication is bleeding. According to **Colson *et al.*** [(15)], the occasional frequency of heavy blood loss ranged between centers (0 to 16%) but was unrelated to in-center heart operational practice. **Christensen et al.** [(16)] they declared that elevated intercostal tube drainage (> 200 ml/hr in any period of one hour, > 2 ml/kg/hr in two consecutive hours, or > 495 ml throughout the initial day) was linked to increased morbidity and deaths.

Postsurgical bleeding, sternotomy for hemorrhage, and blood components transfusion are all linked to worse consequences in open heart surgery. In a big trial of 18,752 participants studied by **Vivacqua *et al.*** [(17)], the reoperation frequency was 3% (2.3-4%) and the reoperation deaths was 8.5 versus 1%. **Mehta *et al.*** [(18)] examined the Society of Thoracic Surgeons National Cardiac Database for 528,686 CABG patients operated on at over 800 hospitals (2004 to 2007). The rate of reoperation was 2.4%, and the deaths for re-explored cases was 9.1% compared to 2% for those non-re-explored. Also, **Elassal *et al.*** [(19)] stated that re-explored class had elevated deaths frequency than non-re-explored cases (15.4% versus 2.53%).

Acute respiratory distress syndrome (ARDS), atrial arrhythmias, renal failure, sepsis, and stroke, as well as lengthy mechanical ventilation inotropic support, were morbidities linked to re-exploration as an independent risk factor [(17)]. Re-exploration cases in the **Elassal** study had a greater rate of deep sternal wound infections DSWI, extended durations of MV, ICU reside, and stay in hospital, and more blood and blood products requirements [(19)]. Potential worse consequences were linked to re-exploration and transfusion needs independently.

Numerous topical hemostatic substances and those prohibiting hemorrhage have been applied after cardiac surgery. There are many topical hemostatic agents to choose from. Apart from the hemostatic effect, some also have wound healing and anti-infective properties[(20)].

In several cardiovascular centers, bone wax is used to stabilize effusive blood loss from the sternal marrow following sternotomy. It is efficient, inexpensive, and thus advantageous[(21)]. A few wax components, however, are not absorbed up by spongious tissue, and microbial seeding may arise[(22)]. Bone wax, uniquely, may be ineffective in geriatric persons and those suffering from osteoporosis.

CoStasis is a mixture of bovine thrombin with bovine micro fibrillar collagen. The findings of collagen trial demonstrated that hemostatic achievement was reached in > than 90% (153/167) of CoStasis class other than 58% (88/151) of control (P = 0.01). The median period to preventing blood loss (42 seconds versus 150 seconds, P = 0.0001) and total hemostasis period (75 seconds versus 252 seconds, P =0 .0001) were evidently elevated with the control group. CoStasis use went without severe side effects[(23)].

ORC (oxidized regenerated cellulose) produces a synthetic clot that lowers pH and causes a caustic consequence[(11)]. It operates through various mechanisms. It establishes both a physical and mechanical boundary. It soaks up serum and grows. It comes back to its gelatinous state.

Mair *et al.* [(24)] located ORC sheets to preoperatively existing sternal fissures in 38 cases with weak sternal bones, promoting the osteo inductive influence of ORC. No patients needed extra surgery due to bleeding or sternal dehiscence. They stated that two cases developed superficial wound infections that were managed with local dressing, but no deep sternal wound infections occurred.

Furthermore, **Nasso *et al.*** [(25)]**,** discovered that the FloSeal group had statistically elevated incidence of successful hemostasis and lesser duration (p < 0.001 both). This conclusion was verified by time-to-event analysis (p = 0.0025). Postsurgical blood loss and blood product transfusion levels were both statistically reduced in the FloSeal group (p < 0.001 both). Revision rates for hemorrhage and slight problems were not statistically distinct among the groups mostly in total cohort, but were significantly lower in the FloSeal class when only cases with overt intraoperative bleeding were regarded (p = 0.04 both)[(25)].

Absorbable gelatin sponges (gel foam) are tiny, aseptic operational sponges, which are made from especially treated, thrombin-free gelatin solution. Also, every sponge is a hemostatic instrument able to absorb and retaining several times its weight in all of the blood inside its meshes, and is totally absorbed in four to six weeks [(26)].

Since gel foam GF is degradable in whole body, the paste type can be used instead of bone wax to prevent osteogenic prohibition. **Taheri** [(27)] utilized powder form gelatin foam on the inter body hole drilled throughout drilling more than 300 anterior cervical operations. Follow-up X-ray films revealed no variations in bone healing between cases who had already been managed without Gel foam paste. In Cloward operations, **Rengachary and Manguoglu**[(28)] provided bovine thrombin to the gel foam paste without adverse allergic reactions. **Harris and colleagues**[(29)] introduced a group of 45 cases who had overall hip replacement surgery. On blood loss cancellous bone surfaces of femoral osteotomies, they used Gel foam paste or sponge with bovine thrombin, or micro fibrillar cellulose. Over a 3-minute interval, they discovered that blood loss was lowered by 85%, 75%, and 47%, respectively. There was no variation in bone healing between the three patients' groups.

Additionally, **Das *et al.*** [(13)] reported a 43-year-old diabetic male presented with acute anterior wall ST increased myocardial infarction and an unusual case of inadvertent distal small diagonal branch perforation recognized post left anterior descending coronary artery revascularization, rescued by gel foam closing.

Intermittent balloon inflation for 30 minutes was unable to wrap off the puncture; due to upcoming delayed (3-6 h) cardiovascular tamponade, gel foam embolization via Caravel micro catheter shut the puncture. Although it is rarely used, this armamentarium should be present in the interventional cardiac research laboratory to manage small vessel punctures (2 mm), for which coated stents are not obtainable in size[(13)].

Moreover, the described a rare of guide wire-induced distal small vessel coronary perforation closed with Gel foam, which saved the patient from late-onset cardiac tamponade; in time, sealing of the coronary perforation is the key to achieving a good peri-procedural outcome. The art of gel foam embolization is quite simple when delivered through a micro catheter, and interventional laboratories dealing with complex coronaries should have the same in their armamentarium to rescue the patient from an uncommon emergency like coronary perforation [(13)].

Our findings supporting those studies. We preferred to use Gel Foam to tamponade bleeding sites under surface of sternum after wire insertion as it has excellent ability to embibe blood and increase in size which leads to pressure on bleeding sites from sternal wires tamponading them. The present study confirmed that gel foam can decrease sternal bleeding (20 % of causes for exploration), and its complications. Statistically higher rates of reopening for bleeding, total blood drainage, blood transfusion and cardiac tamponade in group A compared to group B. Early mediastinitis wasn't not statistically different among two groups, but were lesser in group B, which indicates safety of use of gel foam as regards infection and mediastinitis.

This work underscores the importance of gel foam for reducing the postoperative reopening rate for bleeding from the sternum after cardiac surgery.

CONCLUSION

Gel foam is effective in reducing postoperative blood loss as an assistant to conventional operational approaches for controlling hemorrhage from sternal wires. Its thoughtful application is linked to lower rate of reopening for bleeding and total blood drainage after cardiac surgery.

Financial support and sponsorship: Nil.
Conflict of interest: Nil.

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