Efficacy of a new zeolite-based hemostatic gauze in a gunshot model of junctional femoral artery hemorrhage in swine

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Research

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Abstract

Objective

This work sought to 1) establish a reliable gunshot model of junctional femoral artery rupture in swine that accurately simulates field rescue conditions, and 2) use the gunshot model to compare the efficacy and ease of application of zeolite nanometer hemostatic gauze with other hemostatic materials,

Methods

36 healthy landrace swine (body weight 50 ± 5 kg) were randomly divided into three groups which were treated with Combat Gauze (CG), FeiChuang hemostatic gauze (FG), or standard medical gauze (SG). A gunshot model of femoral artery hemorrhage in landrace swine was used with portable ultrasound to accurately position the wound. After the shooting, when mean arterial pressure (MAP) of swine decreased by at least 30% for 10 seconds, wounds were pressed with standard packing (39 g) of gauze materials for 3 minutes to stop bleeding, and then bandaged with pressure. Blood samples were taken 15 min before injury, then 10 min, 30 min, and 60 min after injury to determine hemodynamic, coagulation, and arterial blood gas indexes. Wound temperatures were taken at 5 min, 10 min, 30 min, and 60 min after injury, and survival times were recorded.

Results

The CG (11.15 ± 3.09 ml/kg) and FG (12.19 ± 3.5 ml/kg) groups had significantly less blood loss than the SG group (16.8 ± 5.14 ml/kg) ($P = 0.04$; $P = 0.039$, respectively). After gauze packing, bleeding in CG (5.85 ± 1.17 ml/kg) and FG (5.37 ± 0.93 ml/kg) groups remained significantly lower than that of SG group (6.93 ± 1.03 ml/kg) ($P = 0.011$; $P = 0.003$, respectively). Wound temperature rose with time for all groups ($p = 0.000$). The wound temperatures in the FG group and the CG group were significantly higher than that of the SG group, ($p = 0.004$ and 0.009, respectively). Survival rates and times were not significantly different among the three groups, though the FG group had the longest average survival time (SD 204.8 s), compared with SG group (SD 177.8 s) and CG (SD 187.5 s) groups. No significant differences in hemodynamics, blood gas, and coagulation were observed among the three groups.

Conclusions

The gunshot model of junctional femoral arterial hemorrhage guided by ultrasound had high accuracy for femoral arterial rupture by bullet wound, and provided consistent and reproducible field-simulation conditions for comparison of hemostatic materials. Feichuang zeolite hemostatic gauze effectively controlled bleeding without excessive heat, as found in other zeolite-based products. However, improvements to application technique, such as a packing device are needed to improve operating time.

Introduction

An analysis of autopsies examining cause of death over 10 years of modern war by Eastridge *et al.*(2012) revealed that nearly 24% of pre-hospital deaths were avoidable, and 91% of which were related to bleeding. Further stratified analysis showed that when bleeding occurs, the primary vital sites are the trunk, junction, and limbs[1]. Meta-analysis of civilian pre-hospital deaths showed that bleeding-related deaths still occur frequently and comprise a substantial portion of potentially preventable causes of death[2]. To reduce preventable deaths by bleeding, Tactical Combat Casualty Care (TCCC) emphasizes the use of tourniquets and hemostatic dressing as standard rescue interventions during the early stages after injury. Effective and economic hemostatic materials applied with appropriate measures are therefore essential to reduce pre-hospital mortality from trauma-induced bleeding. Currently, the well-established, commercially available hemostatic materials include three major categories: biological products, chitosan, and aluminosilicate[3]. Due to the low cost and room temperature stability, the latter two are mainly used in on-site treatment of mass casualty incidents. Research into aluminosilicate-based inorganic hemostatic materials has primarily focused on zeolite and kaolin-derived materials, both of which are biocompatible, effective for *in vitro* coagulation, inexpensive, and are already used in commercial hemostatic products.

Combat Gauze is an aluminosilicate-based hemostatic material that incorporates materials such as kaolin and montmorillonite that exhibit low exothermic effects. Similarly, QuikClot Combat Gauze is a kaolin procoagulant hemostatic material that activates host coagulation pathways to control bleeding[4,5–6]. Its hemostatic effects have been confirmed in animal models and practical applications[7]. Zeolite, a relatively new aluminosilicate-based hemostatic material-cotton hybrid gauze that belongs to the same category has been demonstrated to provide relatively high procoagulant activity *in vitro*. Moreover, zeolite Fei Chuang gauze was shown to enhance thrombin generation *in situ* through formation of a plasma complex with $Ca2^{+}$ and the zeolite surface protein ring. This activity reduces time typically required to capture and bind thrombin in the blood[8]. It exhibits stronger hemostatic properties than other kaolin or zeolite-based inorganic agents, with minimal loss of active ingredients and good ductility[9].

Ongoing comparison of new hemostatic products such as Fei Chuang gauze is necessary to improve the efficacy and affordability for field application, while ensuring safety. However, current models for testing these materials have issues with consistency and parallelism, and do not accurately reflect field conditions for gunshot wounds. To address this problem, we developed a gunshot model junction femoral artery rupture in swine for accurate and reproducible testing of medical materials and techniques under field conditions. We used ultrasound guidance to accurately locate the targeted artery for rupture, and allowed stabilization after 30% decrease in MAP.

In this study, we used a gunshot model of junctional femoral artery rupture in swine to evaluate the hemostatic effects of a new zeolite nanometer hemostatic gauze in comparison with commercially available combat gauze and standard medical gauze by observing blood loss, physiological changes, operating time, and survival time during and after rescue measures.

Methods

Animal Subjects

Forty healthy adult landrace pigs were purchased from Beijing Shichuangshiji Mini-pig Breeding Base (animal license number SYXK 2018-0011) at 3.5 months. Each pig weighed 50 ± 5 kg. The pigs were fed a standard diet and observed for a minimum of five days to ensure they were in good health. Four of the 40 pigs were used for pre-experimental and experimental procedure training, while the remaining 36 were numbered randomly. Eight tests were performed daily. Participating veterinarians and transport personnel were unaware of both the experimental design and the animal and gauze selection. The experimental pigs were randomly placed into three groups: the Combat Gauze group (CG group), the FeiChuang hemostatic gauze group (FG group), and the Standard Medical gauze group (SG group). There were 12 pigs in each group. Twelve hours before the experiment, 36 pigs were deprived of food (water was still available), while ultrasounds were used to exclude swine with abnormalities in organs like the heart and lungs. All swine were dissected after the experiment.

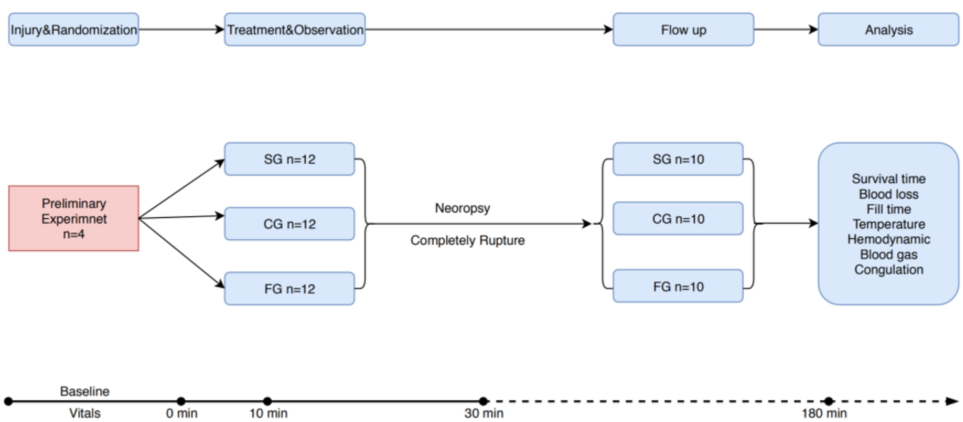
The experimental pigs were anesthetized with an intramuscular injection of anaesthetic (0.1 ml per kilogram of body weight). The anaesthetic is a mixture of Zoletil 50 (Virbac, France, batch number: 76BP) and Sumianxin (Jilin Huamu Animal Health Products Co., Ltd., batch number: 180316), at a ratio of 1:2 by volume. A mixture of Zoletil 50 and Sumianxin, at a ratio of 1:1, was dissolved in 50 ml of a 0.9% NaCl solution and administered via intravenous injection at a speed of 10 ml/h to help maintain the pig's anesthesia. The pigs were then given an intramuscular injection of Meloxicam (Baoding Sunlight Herb Industry Co., Ltd., batch number: 201906006) at a dose of 0.3 mg/kg. Endotracheal intubation was performed with mechanical ventilation. While the pigs were in a supine position on the experimental console, a portable ultrasound diagnostic instrument (VINNO Q Series-7L) was used to catheterize the descending femoral artery and jugular vein. After a successful catheterization, the pigs were connected to a Picco monitor (PULSION PiCCO2 PC8500).

Test Material

The hemostatic gauze was purchased before the experiment. Each group of gauze was standardized, weighing 39 g with a width of 3 inches. They were randomly numbered. The gauze was then packed into the wound. CG (Z-Medica Corporation, Wallingford, CT) is a kaolin-impregnated gauze, which achieves hemostasis by activating the intrinsic coagulation pathway. CG and granular chitosan hemostatic (Celox-A) display similar performance during the initial bleeding, re-bleeding, and survival. Feichuang hemostatic gauze is a new zeolite nanometer hemostatic material (Zeolite Innovation, China), which generates thrombin in situ through the zeolite surface protein ring and forms a Ca^{2+} zeolite plasma complex 2 with high thrombin activity. Its hemostatic effect has been confirmed in animal experiments[9].

Pilot Study

The site of the experiment was the State Key Laboratory of Light Weapon Terminal Lethal Technology at the No. 208 Research Institute of China Ordnance Industries. The shooters were professionally qualified personnel employed by the institute. The guns and ammunition used were also provided by the institute. All shootings were performed by the same shooter, who was unaware of the experimental design and grouping. Two laboratories were prepared in the test site to observe the animals and test their blood specimens. The animal observation laboratory can accommodate 4 animals at the same time, at a constant indoor temperature of 18–24℃. Prior to the experiment, the technicians were divided into different groups responsible for arteriovenous catheterization and endotracheal intubation, on-site treatment and transfer, test recording, inspection, and dissection. All technicians were trained before the experiment and unaware of the animal grouping and hemostatic materials. Pre-tests were conducted to ensure each test phase would run smoothly and meet relevant standards. The flowchart of the experimental design is shown below (Table 1)



Gunshot Wounds

After being successfully anesthetized, the pigs were placed in a lateral position on the test bench, with the abdomen facing the shooter. The two forelimbs and the left hind leg were fixed horizontally, and the right hind was fixed vertically on the test bench to avoid covering the body on the test side. The pig remained stationary for 15 min, after which we collected a blood sample at the TO time point. A portable ultrasound diagnostic instrument (VINNO Q Series-7L) was used to locate the right hind femoral artery. The strongest point of arterial pulsation was selected as the point of impact, and marked the body surface to assist the shooter. The shooter fired a common 9 mm from a distance of 3 meters. Before shooting, everyone was required to take cover from the shooting area. The pigs were considered ready for the experiment once they were bleeding, following the shooting. (Fig. 1)

Hemostatic Treatment

Standardized common medical hemostatic gauze was applied to the bleeding site according to the Tactical Combat Casualty Care (TCCC) once the average arterial pressure of the pig dropped by 30% of the basal value for 10 seconds due to bleeding. The wound was then immediately covered with five pieces of sterile medical gauze and pressed evenly for 3 minutes. A probe thermometer was used to measure the internal temperature of the wound, after which the pressure was applied for another 5 min. The above measurements and operations were then repeated. An emergency bandage was used to dress the wound with appropriate pressure. This process was performed by the same person, and no fluid resuscitation or drug intervention was administered throughout the experiment.

Postmortem Analysis

All dressings and gauze used during the operation were weighed in advance to prevent the loss of bleeding volume from evaporation. Pads, large pieces of gauze, and packing gauze were also weighed in advance. The pads and gauze were placed on the test bench, while large pieces of gauze were placed as a protective shield to collect the splattered blood. The pads and gauze were replaced after packing, while the blood collected was considered the amount bled before hemostasis. The blood absorbed by the gauze and the pad following packing were calculated separately from the bleeding after the packing. The total bleeding volume (ml) = (weight of all dressings after the experiment + weight of blood clot in the wound-weight of blood loss-weight of the dressing before the experiment) / 1.05. The bleeding volume after packing (ml) = (weight of all packing and dressing gauze after the experiment + weight of clot in the wound after test-weight of packing and dressing before the experiment) / 1.05. Indexes including hemodynamics, coagulation, and arterial blood gas were recorded 15 min before the injury, and 10 min, 30 min, and 60 min after the injury. The wound temperature was measured 5 min, 10 min, 30 min, and 60 min after the injury. The pigs were observed until they died, and the time of deaths were recorded. The criteria for death certification was having apnea or MAP values of 0 for 10 consecutive minutes. The time points and indicators are shown below (Table 2).

Table 2

Hemodynamics, Blood gas, and Coagulation indexs

Treatment time-effect	**Total Bleeding Loss/Bleeding Loss After Packing Fill Time /Survival Time** **3-Hour Survival Rate**	
Hemodynamic index	Mean Arterial Pressure (MAP)	PULSION PiCCO2 PC8500
Arterial blood gas index	PH value / Blood Lactic Aacid (LAC) Hematocrit (Hct)	GEM Premier 3000
Coagulation function index	Prothrombin Time (PT) /Fibrinogen (FIB) Activated Partial Thromboplastin Time (APTT)	Wondfo OCG-102

Data Analysis

The statistical analysis in this study is based on the SPSS 20.0 software. All measurement data were in accordance with or approximated normal distribution after normality test. Single factor analysis of variance was used for indexes including total bleeding volume, bleeding volume after packing, and hemostatic operation time. Overall survival rates were evaluated using Pearson's x ^ test. The overall effect of each index over time was compared using repeated measures analysis of variance. Greenhouse-Geisser tests were used to correct the data that did not coincide with sphericity test. Pairwise comparisons were performed using LSD-t post hoc tests, and Friedman rank sum test was applied on non-normal data. $P < 0.05$ was taken as a criterion for statistically significant difference.

Results

1. Basic Information

In this study, 36 landrace swine were selected and randomly sorted into three experimental groups. The pigs were approximately 3.5-months-old, with an average weight of 53.49 ± 2.15 kg. Six swine (two from each group) were excluded from the experiment due to the post-operative results of dissection which indicated that the arteries were not completely ruptured. The remaining 30 swine were included in the statistical analysis. (Table 3).

Table 3
Baseline of the Groups

Group/Number (N)	SG (n = 10)	CG (n = 10)	FG(n = 10)	P
Male n(%)	4(40%)	7(70%)	4(40%)	0.397
Weightmean (SD)	54.6(2.01)	52.7(2.67)	52.8(1.48)	0.191

2. Volume Of Blood Loss And Operating Time

In order to determine the efficacy of Feichuang hemostatic gauze in reducing blood loss compared to Combat Gauze, we induced gunshot wounds to the femoral artery and first measured the differences in blood loss before and after filling. To reduce individual differences, the bleeding volume per kg of body weight (ml/kg) was used as the evaluation index. We found that the total bleeding volumes of the FG (12.19 ± 3.5 ml/kg; P = 0.04) and CG groups (11.15 ± 3.09 ml/kg; P = 0.039) were significantly lower than that in the SG group (16.8 ± 5.14 ml/kg). The bleeding volumes in the FG (5.37 ± 0.93 ml/kg; P = 0.003) and CG groups (5.85 ± 1.17 ml/kg; P = 0.011) remained significantly lower than that in SG group (6.93 ± 1.03 ml/kg) after packing (Fig. 2A).

We then sought to identify potential differences in the ease and efficiency of packing between the FG material and other gauzes through comparison of time used to fill the wounds. The results of this comparison revealed significantly greater operating time (in seconds) between the FG (261.00 ± 54.64 s) and CG (198.70 ± 37.72 s) hemostatic materials ($P = 0.007$), but not between the FG and SG (229.20 ± 48.06 s) ($P = 0.144$), or between CG and SG materials ($P = 0.161$) (Fig. 2B). These results indicate that the FeiChuang gauze was more effective at decreasing blood loss, but required more time to fill the wound.

4. Comparison of wound temperature and indexes for hemodynamics, coagulation, and blood gas

To further compare the efficacy of FG gauze with other packing gauzes, we then measured wound temperature in each group at different time points, including 5 min, 10 min, 30 min, and 60 min after packing. We found that wound temperature significantly increased over time ($P = 0.000$) for the FG and CG groups compared to the SG group ($p = 0.004$; $p = 0.009$, respectively). However, no significant difference in wound temperature was observed between the FG and CG groups ($p = 0.698$), which ranged from 38.8–39.6℃ and 38.5–39.4℃, respectively (Fig. 3).

We then compared physiological indicators between experimental groups to identify any adverse effects of Fei Chuang gauze on blood pressure, coagulation, and changes in dissolved gas in the blood stream. We found that mean arterial pressure ,activated partial thromboplastin time, lactic acid and hematocrit all significantly changed over – 15 min, 10 min, 30 min, and 60 min time points within each of the experimental groups (MAP $P = 0.01$,APTT $P = 0.001$,LAC $P = 0.000$,Hct $P = 0.001$). However, no differences were observed between groups for any of these indexes at any of the timepoints. Each index was tested by pairwise comparison using the LSD test, with a significance threshold of $P < 0.05$. Taken together, these results strongly suggest that (new material) functions similarly to CG in maintaining a slightly elevated wound temperature, and does not incur any additional adverse effects related to blood physiology.

5. Comparison Of Survival Rates

We then compared survival time among all experimental groups to confirm that no additional factors associated with (new material) contributed to adverse post-operative outcomes. We found that all swine from each of the three groups survived for greater than one hour, and moreover, 100% of the swine in the CG and FG groups survived for at least three hours. In contrast, one swine in the SG group died before three hours, resulting in a 3-hour survival rate of 90% for the SG group. However, the survival rate was not significantly different in Pearson chi-square comparisons among all three groups ($p = 0.355$) (Table 4), although the difference between the FG group, which exhibited the longest average survival time was significantly greater than that of the SG group, which had the shortest average survival time. These findings indicate that (new material) functions as well or better as combat or standard medical gauze for prolonging survival time following rupture of the femoral artery.

Table 4
Survival time (minutes) for swine dressed with different hemostatic materials

Group	Survival time	Smin	Smax	P
SG	177.8 ± 9.10	165	193	
CG	187.5 ± 16.7	180	234	0.395*
FG	204.8 ± 39.07	180	278	0.023**
Data expressed as Mean Values ± SD (minutes),				
P=0.395*: CG group VS SG group(LSD-t test),				
P=0.023**: FG group VS SG group(LSD-t test),				
P = 0.135: CG group VS FC group.(LSD-t test)				

Discussion

To address challenges associated with development of low-cost zeolite-based hemostatic materials, such as exothermic tissue damage and difficulties with surgical tissue removal, we established a stable gunshot model for junctional femoral artery hemorrhage in swine which uses gauze packing type as the variable for random grouping. Combat gauze has been used as a gold standard for comparison in many experiments since its FDA approval in 2013[7]. In comparison with combat and standard medical gauzes, we found that zeolite nanometer gauze performed as well or better than combat gauze, and both of which showed greater reduction of total blood loss and post-packing volume blood loss than the standard medical gauze. Dressing the wound with proper pressure and hemostatic agent, the 3-hour survival rate for all swine was 100%, except for one CG swine that died within 3 hours, which is consistent with survival rates found by Alam [10]*et al* in lethal femoral artery hemorrhage model.

In order to test the novel zeolite material in a hemorrhage model that more accurately reflects real-life gunshot trauma, we developed a controlled “gunshot junctional femoral artery hemorrhage” model for swine that incorporates an actual bullet wound to the femoral artery, thereby precisely replicating the arterial rupture and damage to surrounding tissue that gauze materials must accommodate in field conditions. Wound conditions, including blood loss, showed low variability between test subjects, as well as lower overall blood loss than observed in traditional, surgical models for arterial rupture[11,12]. In comparison with the traditional model that uses a 6 mm diameter femoral artery rupture punch, free bleeding for 30 s or 45 s, and a weight equivalent to a 2-pack of standard medical gauze, 2 min of operation time, 3 min pressure applied to the wound, and fluid resuscitation. Although these measures increased the severity of bleeding to a certain extent, resulting in more pronounced hemostatic effects between materials. However, this method does not closely resemble true gunshot injury, leading us to develop a more realistic simulation of gunshot hemorrhage.

Notably, we used portable ultrasound to accurately locate the femoral artery prior to administering the bullet wound. During preliminary data collection, the ballistic trajectory was determined with the shooter, and the point of entry was selected for an artery segment densely wrapped by surrounding muscle, 2–3 cm above the deep groin, to ensure minimum hit rate of 80%. In a computational model for junctional femoral artery rupture, the predicted rate of blood loss ranged from 500–1,500 ml/min[13]. With this model, 180 s of non-intervention and blood loss reaching 35% results in the cardiovascular system reaching the limit of its compensatory capacity with no stabilizing trend[13]. In preliminary experiments, we attempted delayed intervention at 40 s and 25 s of free bleeding. However, using standard intervention for bleeding and on-site wound management principles (*i.e.*, wound packing, pressure dressing, and injury control resuscitation), we found that under real stress conditions, the blood squirted heavily and animals only survived for 10 min and 30 min, respectively.

These findings sharply contrasted with results generated with previous laboratory animal models that were given a compensatory stabilization period[14]. Therefore, to avoid decompensated hypotension before treatment, we ultimately selected the intervention point when MAP decreased by 30%. Furthermore, since the decrease in MAP may be due to a transient rapid response, the 30% decrease of MAP was necessarily maintained for 10 seconds. During the packing process, the bleeding continued, then gradually stopped, resulting in a 35% total loss, within the acceptable range for examination hemostatic effects. We avoided splenectomy and fluid resuscitation because these procedures alter the inherent coagulation response and potentially increase the volume of blood loss[15].

Post-experimental dissection revealed that the bullet caused a small, 2.5 cm diameter entrance wound and a large exit wound, with almost 90% of gunshots resulting in obvious tissue damage consisting of fractures, and ruptured veins and muscles. Dissection resulted in limited femoral contracture and a degree of spasm in the femoral artery fracture, although we found no closed fracture or proximal vessel thrombus. Several thrombi appeared around the gap between gauze and surrounding tissue, which were cleared by easy removal of the zeolite gauze. The change of MAP was consistent with previous reports[16], decreasing at 15 minutes after injury, and then gradually stabilizing. However, without fluid resuscitation, the overall stable level (> 100 mmHg) was higher than in previous reports, ~ 60–65 mmHg[17]. This difference may be related to the small bullet entrance and relatively intact muscle surrounding the artery, which increased the hemostatic effect of packing. In addition, we cannot exclude the possibility that a large number of inflammatory factors were released in response to the tissue damage which promoted coagulation[18], subsequently leading us to opt against liquid resuscitation. This novel gunshot model for femoral artery hemorrhage enabled the reaction of mixed factors that appear in real gunshot wounds, thus providing a test for hemostatic materials that accurately represent their field application.

Zeolite is widely used as an effective and economical hemostatic agent because its vesicular structure exhibits high water absorption and promotes coagulation, but also releases considerable heat in the process that can potentially burn surrounding tissue[7,19,20]. At present, zeolite-related inorganic hemostatic materials, such as QuikClot ACS (particles and sponges) use hydrated zeolite porous grids to reduce thermal damage at the cost of reducing hemostatic efficiency. Notably, QuikClot ACS steadily generates heat during the hemostatic process, reaching 80°C in 5 min, then decreasing at 15 min, and stabilizing to body temperature at 30 min[21]. In our experiments, wound temperatures in CG group and FG group ranged from 38.5–39.4°C, thus demonstrating improvement to the heat-related risks associated with QuikClot ACS. Moreover, the zeolite Fei Chuang gauze retained strong hemostatic properties, comparable to combat gauze, with substantially lower total blood loss of 12.19 ml/kG following application compared to QuikClot ACS+ (15.8 ml/kg) or Wallingford Combat Gauze (37.4 ml/kg)[11,12]. Future studies will include extensive pathological examination of surrounding tissues to definitively exclude tissue damage caused by hemostatic materials, though we observed no superficial burns, nor changes to pH, hemodynamics, and coagulation pathways.

Operation time and ease of application are central factors in field treatment. In this study, we found that packing time ranged from 198.7 s to 261 s, with zeolite nanometer hemostatic gauze requiring more time than other treatments, thus representing a critical disadvantage in the field. The difficulty in application may be related to the rough texture caused by minerals on the gauze surface. To overcome this issue with deep junctional wounds, a standardized sterile injector could be used as a packing device, or injectors filled with fast-expanding hemostatic gauze could potentially reduce operation time. Given the necessity for efficiency in the field, future studies can explore the optimization of gauze application methods.

Conclusion

Here, in this work, we developed a novel model for gunshot junctional femoral artery hemorrhage in swine under ultrasound guidance. By resolving issues of low consistency and parallelism within experiments inherent in previous models, we achieved an 80% success rate for accurate arterial rupture. This model for predictable death in complex rescue environments allows tighter control of injury, physiological stability, and experimental (*i.e.*, frontline) conditions. Furthermore, we employed this model to demonstrate the high efficacy a new zeolite nanometer hemostatic gauze for control of bleeding and minimization of thermal tissue damage in comparison with other dressings. Further study will lead to more efficient methods of application necessary for wide clinical or field adoption.

Declarations

Ethical Approval and Consent to participate

The treatment of animals in this study complies with animal ethics standards and passed the animal experimental ethical inspection by Institutional Animal Care and Use Committee in China. (Grant No. SC2019-06-013).

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Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conception and design: Jing Wang，Tanshi Li，

Analysis and interpretation: Jing Wang, Cong Feng, Heng Zhang,

Data collection: Jing Wang, Junkang Wang,Fei Pan,Hengliang Zhang,Chenyu Guo

Writing the article: Jing Wang

Critical revision of the article: Jing Wang,Heng Zhang

Final approval of the article: Cong Feng,Tanshi Li

Statistical analysis: Jing Wang ,Junpeng Luo

Obtained funding: Tanshi Li

Overall responsibility: Jing Wang,Tanshi Li

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Consent for publication

Not applicable.

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Figures

Figure 1

A portable ultrasound diagnostic instrument (VINNO Q Series-7L) was used to locate the right femoral artery Transient blood flow when the femoral artery bursted.

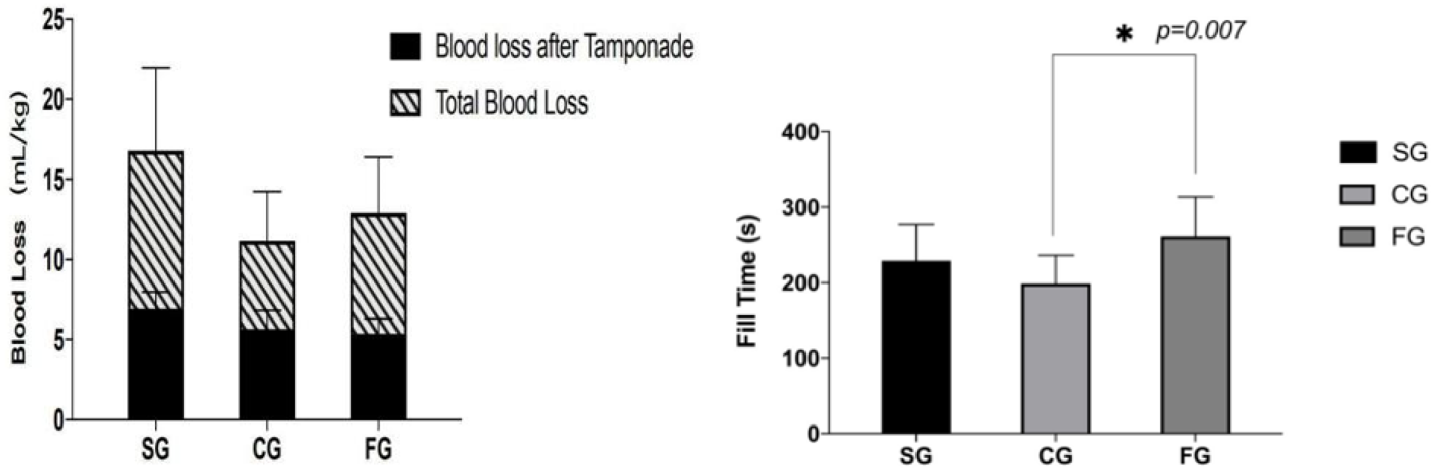

Fig 2(A) Fig 2(B)

Figure 2

(A). Differences in blood loss and operating time between FeiChuang gauze and Combat Gauze . Total blood loss and blood loss after application of tamponade in Ml/kG bodyweight. Data represent mean + SD. (B)Time required to fill wound (in seconds). Data represent mean + SD. With Single factor analysis.

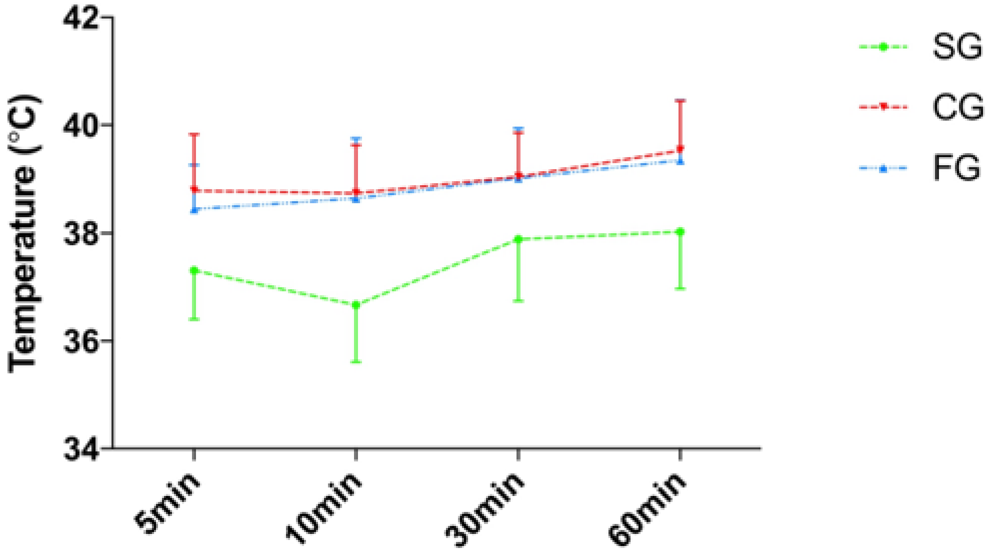

Figure 3

The changes of Wound Temperature in three groups.Temperature is measured in Degrees Celsius(°C).