

# Intraoperative Fluid Overload Predicted Postoperative Debridement in Major Sacrum Tumor Resection: A Retrospective Case-control Study

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## Research

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# Abstract

**Background** Sacrum tumor resection is with high morbidity due to complex anatomy, sacral nerves involvement, massive bleeding and tumor malignancy. Risk factors related with complications following sacrectomy were not clearly defined.

**Method** Anesthetic database of Peking University People's Hospital, Beijing, China was searched for all patients (aged 14-70 years of age) received sacrum tumor surgery from 2014 to 2017. As part of the bleeding control program, intra-aortic balloon occlusion (IABO) was applied to patients whose tumor volume was more than 200 cm<sup>3</sup>, a tumor that had invaded cephalad to the S2-S3 disc space, or tumor with an abundant blood supply.

**Results** Finally 355 patients who underwent sacrectomy were included in this study, among whom 278 patients received intraoperative IABO, whose duration of aortic occlusion was 72±33 min. Extensive hemorrhage (>2000 ml) occurred in 61(21.9%) patients receiving IABO.

Fifty-six patients in IABO Group required postoperative debridement due to wound infection. The independent risk factor identified by logistic regression was fluid excess (calculated as volume infused (crystalloid, colloid, CRC and FFP), minus blood loss and urine output, divided by body weight (kg)), and decision tree analysis found that the cut-off point for fluid excess was 38.5 ml/kg. Then propensity score matching of intraoperative blood loss and aortic occlusion duration was adopted for patients whose fluid excess >38.5 ml/kg and those whose was lower or equal. Afterwards, 91 pairs of patients were generated. Fluid excess was significantly different (46 vs. 30 ml/kg, P=0.000) for patients whose fluid excess was >38.5 ml/kg, and required more postoperative debridement (24 (26.3%) vs. 12 (13.1%), P=0.000) than those whose was lower or equal.

**Conclusion** In this retrospective cohort study about sacrum tumor resection, duration of aortic occlusion and anesthesia were identified as predictors for massive bleeding. Fluid overload was related with high morbidity and studies are needed to further improve clinical prognosis.

## Key Point Statement

**Question:** What are the risk factors for postoperative surgical debridement for major sacrum tumor surgery requiring temporary aortic occlusion?

**Findings:** Fluid overload is a risk factor for postoperative surgical debridement and prolonged length of stay.

**Meaning:** Optimal fluid repletion strategy for major surgeries should avoid fluid overload and ideal infusion strategy should be investigated.

## Introduction

Sacrum tumor resection is characterized by massive bleeding due to complex anatomy and abundant blood supply to the tumor(1). Surgical removal with adequate margins remains the most definite treatment strategy, but perioperative management could be complicated due to sacral nerves involvement, excessive bleeding and tumor malignancy(2). Nevertheless, oncologic control has been improved by dramatic technical revolutions, including extremity saving strategy, one-stage sacrum reconstruction and blood loss control measures (intra-aortic balloon occlusion) in recent years(3)(4).

Blood loss control measures are crucial in nowadays surgical removal of sacrum tumor(5). Other than aortic clamping, intra-aortic balloon occlusion (IABO) could be applied to reduce distal arterial blood flow and substantially decrease intraoperative blood loss, and shorten duration of surgery according to our investigation(6). Thereafter, IABO would be used to lower surgical blood loss in patients with identified risk factors, including a tumor that invades cephalad to the S2-S3 disc space, has a volume of  $>200\text{ cm}^3$ , or an abundant blood supply(7)(8).

In this scenario of massive bleeding, fluid repletion and blood product transfusion are two main measurements to stabilize macrocirculation and microcirculation. Even though goal-directed approach using flow-based hemodynamic monitoring showed benefit, the optimal fluid infusion strategy for major surgery is currently not feasible due to a lack of evidence. Nevertheless, infusing too much could result in tissue edema, which is as harmful as infusing too little(9). As shown in our previous study involving 387 patients undergoing sacrectomy from 1997 to 2009, 113 (29.2%) patients suffered from wound infection or dehiscence, and the maximum infusion volume being 10 L(10). Thereafter we hypothesize that fluid overload could predict the incidence of wound dehiscence and postoperative debridement in major sacrum resection.

In this retrospective cohort study, we collected sacrum tumor surgery data within 3 years, aiming to investigate main perioperative predictors of postoperative debridement especially the effect of fluid overload on the occurrence of debridement after sacrum tumor resection. Specifically, we studied 355 consecutive patients undergoing sacrectomy by one senior surgeon.

## Methods

The anesthetic database of Peking University People's Hospital was searched for all patients (aged between 14-70 years of old) who received sacrum tumor surgery under general anesthesia from May 1, 2014 to April 30, 2017. All surgeries were performed by one senior surgeon, Dr. Guo Wei. Anesthesia records and medical charts were reviewed to document anesthesia management details, blood loss, fluid therapy, pathological diagnosis and length of stay. Emergent procedures or patients less than 14 years of old were excluded. The study protocol (2018PHB017) was approved by the Ethics Committee of Peking University People's Hospital, Beijing, China (Chairperson Prof. S. Mu), which waived the requirement for informed consent because of the retrospective design. This article complied with STROBE guidelines for cohort study.

### *Anesthesia management*

All patients were induced with intravenous anesthetics, propofol 1.5-2.5 mg/kg, sufentanil 3ug/kg and rocuronium 0.6 mg/kg. Anesthesia maintenance was accomplished by sevoflurane inhalation, continuous infused propofol and remifentanil to achieve bispectral index (BIS) range of 40-60. An arterial line through one radial artery and a central line through the right internal jugular vein were established after anesthesia induction.

### *Balloon insertion and intraoperative use*

All patients were assessed about their risks of extensive bleeding and high-risk patients would receive temporary intra-aortic balloon occlusion during surgery.

For patients indicated for temporary aortic occlusion, their right femoral artery was punctured after anesthesia induction, with an 11F percutaneous introducer sheath (CROSSOVER; Cordis), through which a double-lumen balloon catheter (MAXILD; Cordis, a Johnson & Johnson company, Bridgewater, New Jersey) was inserted into the abdominal

aorta. Under the guidance of an X-ray C-arm, the balloon was positioned distal to the superior mesenteric artery and both renal arteries (Fig 1).

When the surgeons were ready to remove the tumor mass, the aortic balloon catheter was inflated to occlude the aorta completely. When tumor removed, sacrectomy finished and pedicle screws were positioned, the aortic balloon was deflated (Fig 1).

### ***Intraoperative bleeding and fluid therapy***

The intraoperative blood loss was estimated by the surgeons and anesthesiologists and included the exact volume of suction and the estimated volume absorbed by sponges and dressings. Concentrate red cells (CRC) were given when hemoglobin decreased to 90 g/L. Usually frozen fresh plasma (FFP) was prescribed in a 1:1 ratio with CRC. For intraoperative fluid therapy, Ringer's lactate and hetastarch (Voluven<sup>®</sup> 130/0.4, maximum volume being 1000 ml) were used to maintain a central venous pressure above 4mmHg. Blood pressure less than 90/60 mmHg would be treated with ephedrine 6 mg.

### ***Recovery and Follow-up Study***

After the surgery most patients recovered and were extubated in postoperative care unit. For patients more than 70 years of age, suffering from intraoperative extensive hemorrhage (>2000ml), with concurrent uncompromised diseases, were indicated to intensive care unit (ICU) admittance.

### ***Outcome measurement***

Surgical debridement was undergone in the operating room and recorded, as well as prolonged length of stay (>28 days). Other complications related with sacrum resection included extensive hemorrhage (>2000 ml), postoperative intensive care unit (ICU) admittance, cerebrospinal fluid (CSF) leak, thrombosis of femoral artery (due to aortic balloon insertion, indwelling or extraction). Fluid excess was calculated as volume infused (crystalloid, colloid, CRC and FFP), minus volume lost (blood loss and urine output), divided by body weight (kg)).

### ***Statistical analysis***

Statistical analysis was performed using the SPSS 20.0 statistical software package (SPSS Inc., Chicago, IL, U.S.A.). Continuous variables are expressed as mean  $\pm$  SD or medians with interquartile range and categorical variables as numbers and percentages. Chi square or Fisher's exact test was used for univariate analysis. Multivariate logistic regression was adopted to identify risk factors for excessive hemorrhage (>2000 ml), postoperative debridement and prolonged length of stay (>28 days).

Area Under the ROC curve (AUC) was used to measure the calibration and discrimination of the logistic regression model. The cut-off point for different risk variables would be identified through Decision Tree Analysis, i.e. Classification and Regression Trees.

Propensity score matching was carried out between patients whose fluid excess was beyond the cut-off point and whose fluid excess was lower or equal, in order to reduce the effect of potential confounding factors and the collinearity of blood loss and fluid excess. The propensity score was calculated by logistic regression analysis using the following covariates: age, gender, height, body weight, ASA grade, duration of aortic occlusion, duration of surgery and duration of anesthesia, tumor pathology and blood loss. The nearest-available neighbor matching method with a

caliper radius score of 0.02 was adopted to pair the participants from each group in a 1:1 ratio based on the propensity score similarities.

## Results

There were 410 patients identified using “Sacrum tumor” as a key word in diagnosis and the surgeon “Dr. Guo Wei” in the electronic anesthesia record system from May 1, 2014 to April 30, 2017. After reviewing all these patients’ charts, 55 patients were excluded due to actual surgery were on the lumbar spine and sacrum simultaneously (n=40) or on the pelvis (n=15). Finally 355 patients who underwent sacrectomy or total sacrum removal were included in this study. Among these patients, 278 received temporary intra-aortic balloon occlusion (Fig 2).

All patients underwent posterior sacrum tumor resection and reconstruction, except 8 patients received En bloc resection with reconstruction through posterior approach only.

Duration of intra-aortic balloon occlusion was  $72\pm 33$  min, 4 out of 278 patients required two episodes of occlusion (occlusion duration 85&50, 65&25, 80&120, 150&130 min) due to advanced disease or high malignancy.

Patients with IABO suffered from more surgical debridement (56(20.1%) vs. 3(3.9%),  $P=0.001$ ). Extensive hemorrhage occurred in 61 (21.9%) patients with IABO and 2 (2.59%) patients without IABO (Table 1).

### ***Risk assessment of postoperative debridement***

Fifty-six patients in IABO Group required postoperative debridement in the operating room under general anesthesia due to wound dehiscence. The AUC of multivariate regression was 0.650 (0.567, 0.732),  $P=0.001$ . Decision tree analysis showed that for those whose intraoperative fluid excess exceeded 38.5 ml/kg were more likely to suffer from wound infection, 32/111 (28.8%) vs. 24/167 (14.4%), OR 2.302 (1.246, 4.251),  $P=0.008$  (Fig 3).

### ***Propensity score matching for fluid excess analysis***

In order to reduce the effect of potential confounding factors and the collinearity of blood loss and fluid excess (Fig 4), propensity score matching was carried out between patients whose fluid excess was more than 38.5 ml/kg and whose fluid excess was lower or equal. The propensity score was calculated by logistic regression analysis using the following covariates: age, gender, height, body weight, ASA grade, duration of aortic occlusion, duration of surgery and duration of anesthesia, pathology and blood loss. After calculating the propensity scores, we used the nearest-available neighbor matching method with a caliper radius score of 0.02 to pair the participants from each group in a 1:1 ratio based on the propensity score similarities (Table 2).

Ninety-one matched pairs were generated using the propensity score matching, which was effectively performed for both groups to counterpoise each preoperative variable. After matching, the duration of aortic occlusion, surgery and anesthesia, and blood loss were comparable between two groups, but fluid excess was significantly different (46 vs. 30 ml/kg,  $P=0.000$ ). Patients in fluid excess group received more crystalloid/ colloid, red cells and plasma infusion, and more patients had surgical debridement 24 (26.3%) vs. 12 (13.1%),  $P=0.000$ .

### ***Risk assessment of other adverse events***

Extensive hemorrhage (intraoperative blood loss >2000ml) occurred in 61 (21.9%) patients with IABO. Multivariate analysis revealed that longer duration of aortic occlusion and anesthesia contributed to excessive bleeding (Fig 3).

The final logistic regression model exhibited excellent discrimination and acceptable calibration, with the AUC being 0.779 (0.713, 0.844),  $P=0.000$ .

Seventeen patients in IABO Group were transferred to ICU, the independent risk factor was intraoperative excessive bleeding, 11/61 (18.0%) vs. 6/217 (2.8%), OR 6.148 (1.764, 21.427),  $P=0.000$ .

Forty-nine patients in IABO Group suffered from prolonged hospital stay, the independent risk factor was postoperative debridement, 31/56 (55.3%) vs. 18/222 (8.1%), OR 14.053 (6.882, 28.699),  $P=0.000$ .

## Discussion

In this retrospective case-control study about 355 sacrectomy, fluid overload was a risk factor for postoperative surgical debridement. Excessive bleeding and debridement contributed to postoperative ICU admission and prolonged hospital stay respectively.

Large fluid shift was inevitable in sacrum tumor resection because it was characterized by massive bleeding, with 21.9% patients in IABO group suffering from massive hemorrhage, and the maximum blood loss during our study period being 5500 ml. The main predictors for massive bleeding were duration of aortic occlusion and anesthesia, instead of any specific pathology type, recurrent tumor or total en bloc. This finding could be attributed to the routine use of IABO to high-risk patients. According to our previous studies, the IABO could decrease intraoperative blood loss from 3935 ml to 2236 ml for patients with similar tumor characteristics, such as tumor pathology, tumor volume and involved sacrum area(7). Patients in IABO group were at high risk to develop extensive hemorrhage due to large tumor mass or abundant blood supply, but with the successful application of temporary aortic occlusion, the median blood loss was 1416 ml. Meanwhile, there were altogether 16 pathology types included in our study, thus it is not powered to identify the difference among different pathology types. But Chondrosarcoma and Giant-cell tumor tend to have large volume of blood loss<sup>(6)</sup>. Recurrent tumor was not a risk factor for excessive bleeding which was proven in our previous study.

The fluid repletion strategy should be established because surgical resection remains the mainstay treatment even though sacrum tumor resection is difficult(11)(12). In addition, the disease burden could be tremendous with incidence for chordoma being 0.08 per 100 000 patients(13), chondrosarcoma 0.5 per 100 000(14), and Ewing's sarcoma 0.2 per 100 000 patients per year(15). Surgical removal of sacrum tumor is difficult because of complex anatomy, sacral nerves involvement, massive bleeding and tumor malignancy.(16) Optimal oncological control could be achieved through adequate margins resection in order to prevent recurrence and improve event-free survival.(17) (18) According to a report from our hospital, En bloc sacrectomy through posterior-only approach significantly reduce surgery burden and stress on the patients, with 7 out of 10 patients having tumor-free survival in 29 months follow-up.(19)

Fluid therapy is crucial, complicated and affects clinical outcomes in major surgeries(9, 20). In our study, the fact that fluid overload led to postoperative debridement and sequential longer hospital stay, could be explained by the negative effect brought by large volume of infusion such as tissue edema. Actually fluid excess and blood loss had a linear correlation shown in Figure 4, and the maximum fluid excess is 100 ml/kg during this three-hour surgery. In order to eliminate the collinearity between blood loss and infusion, propensity-matching score was applied. Ninety-one matched pairs of patients were generated with similar blood loss, similar duration of aortic occlusion, surgery and anesthesia. But fluid excess was significantly different and more patients suffered from surgical debridement than those whose fluid excess lower or equal to 38.5 ml/kg. Given the fact that median blood loss of 1100 ml,

repletion of blood loss with 780 ml concentrate red cells and 600 ml FFP, the infusion of 3740 ml crystalloid and colloid at the same time should be of concern.

There are several reasons for generating big fluid excess (46 ml/kg) in this major bleeding procedure. First, the optimal fluid management protocol was not established due to lack of evidence. Second, using CVP and blood pressure as the goal of resuscitation is not recommended in goal-directed therapy(21). Third, dynamic assessment of fluid responsiveness and cardiac output should be considered. But the prone position prohibited the use of esophageal cardiography, and the implication of Flotraq in prone position and the aortic occlusion should be investigated in future studies(22). Fourth, the vasopressors are indicated in the circumstance of dynamic monitoring of fluid responsiveness to balance the  $V_{\text{stressed}}$  and  $V_{\text{unstressed}}$ (23).

The red cell transfusion threshold of 90 g/L was adopted in this study to reduce homologous transfusion. The postoperative hemoglobin of 83 g/L showed the plausibility of our red cell transfusion protocol by not targeting at hemoglobin more than 90 g/L. From the perspective of patient blood management, preoperative anemia should be corrected by using ferrum/erythropoietin(24), and using intraoperative cell salvage. The institutional patient blood management program is determining detailed bundles to decrease blood product consumption and fluid therapy protocol in order to improve patients' outcome. Nevertheless, many aspects of pathologic alterations brought by the main measurement of blood loss control, IABO application, were conquered by minimizing aortic occlusion duration, gradual release of the balloon and close monitoring of blood gas analysis(8). Meanwhile, patients with IABO suffered from comparable happenings of ICU admittance, CSF leak or thrombotic/embolic events, except surgical debridement.

This study may be criticized for focusing on patients' in-hospital outcomes only and the nature of a retrospective design. We managed to present anesthesia management for this kind of complicated surgery with large fluid shift, but follow-up information was not collected to investigate patients' walking ability, visceral function or pain intensity after discharge. Further studies were mandatory to investigate anesthesia refinement and patient blood management on long-term outcome such as tumor recurrence and quality of life.

In conclusion, in this retrospective cohort study about sacrum tumor resection, fluid overload was related with high morbidity and studies are needed to further improve clinical prognosis.

## Declarations

*Ethics approval and consent to participate:* The study protocol (2018PHB017) was approved by the Ethics Committee of Peking University People's Hospital, Beijing, China (Chairperson Prof. S. Mu), which waived the requirement for informed consent because of the retrospective design.

*Consent for publication:* Not applicable.

*Availability of data and materials* Mendeley Data, V2, doi: 10.17632/6rrtmbsxtt.2

*Competing interests* The authors declare that they have no competing interests

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*Authors' contributions*

HZ helped with study design, conduct of the study and manuscript preparation.

YCS helped with data collection.

SD helped with data collection.

YF helped with study design.

All authors read and approved the final manuscript

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## Tables

Table 1. Demographic, surgical, anesthetic data and clinical outcomes				
	With aortic balloon (n=278)	Without aortic balloon (n=77)	Statistical value	P Value
Male Gender	148 (53.2%)	41 (53.2%)	0	0.999
Age (years)	45 ± 15	53 ± 16	4.081	<0.001*
Height (cm)	165.6 ± 6.3	166.1 ± 6.8	0.63	0.26
Weight (kg)	65.1 ± 9.0	66.0 ± 9.8	0.166	0.434
ASA classification (n)			5.73	0.125
<i>I</i>	90	20		
<i>II</i>	176	49		
<i>III</i>	11	8		
Diagnosis (n)			0.224	0.894
<b>Benign</b>	100 (35.9%)	28 (36.3%)		
<b>Malignant</b>	140 (50.3%)	37 (48.1%)		
<b>Metastatic</b>	38 (13.7%)	12 (15.6%)		
Recurrent tumor (n)	92	20	1.415	0.234
Total En bloc (n)	8	0	2.267	0.132
Duration of surgery (min)	206 ± 63	126 ± 43	-12.928	<0.001*
Duration of anesthesia (min)	286 ± 64	200 ± 56	-10.6	<0.001*
Duration of Aortic Occlusion (min)	72 ± 33	0	-19.1	0.0*
Hemoglobin before surgery (g/L)	102 ± 7.5	100 ± 6.9	2.106	0.036*
Hemoglobin after surgery (g/L)	83.5 ± 5.0	102 ± 12	-13.214	<0.001*
Blood Loss (ml)	1100 (800)	600 (625)	3.308	<0.001*
CRC Infused (ml)	600 (480)	260 (520)	3.920	<0.001*
FFP Infused (ml)	400 (600)	0 (200)	4.037	<0.001*
Fluid excess (ml/kg)	35 (18)	20 (12)	3.586	<0.001*
Complications				
<b>Extensive Blood Loss (&gt;2000 ml) (n(%))</b>	61 (21.9%)	2 (2.59%)	15.459	<0.001*
<b>Debridement (n(%))</b>	56 (20.1%)	3 (3.9%)	11.49	0.001*
<b>ICU admittance (n (%))</b>	17 (6.1%)	6(7.8%)	0.28	0.597

<b><i>Cerebrospinal fluid leak (n(%))</i></b>	13 (4.0%)	1(1.3%)	1.816	0.178
<b><i>Thrombosis (n(%))</i></b>	6 (2.2%)	2 (2.6%)	0.0528	0.818
Length of Stay (days)	25 (10)	20 (13)	-4.275	<0.001*
<b><i>Prolonged hospital stay (n(%))</i></b>	49 (17.6%)	5 (6.4%)	5.794	0.016*

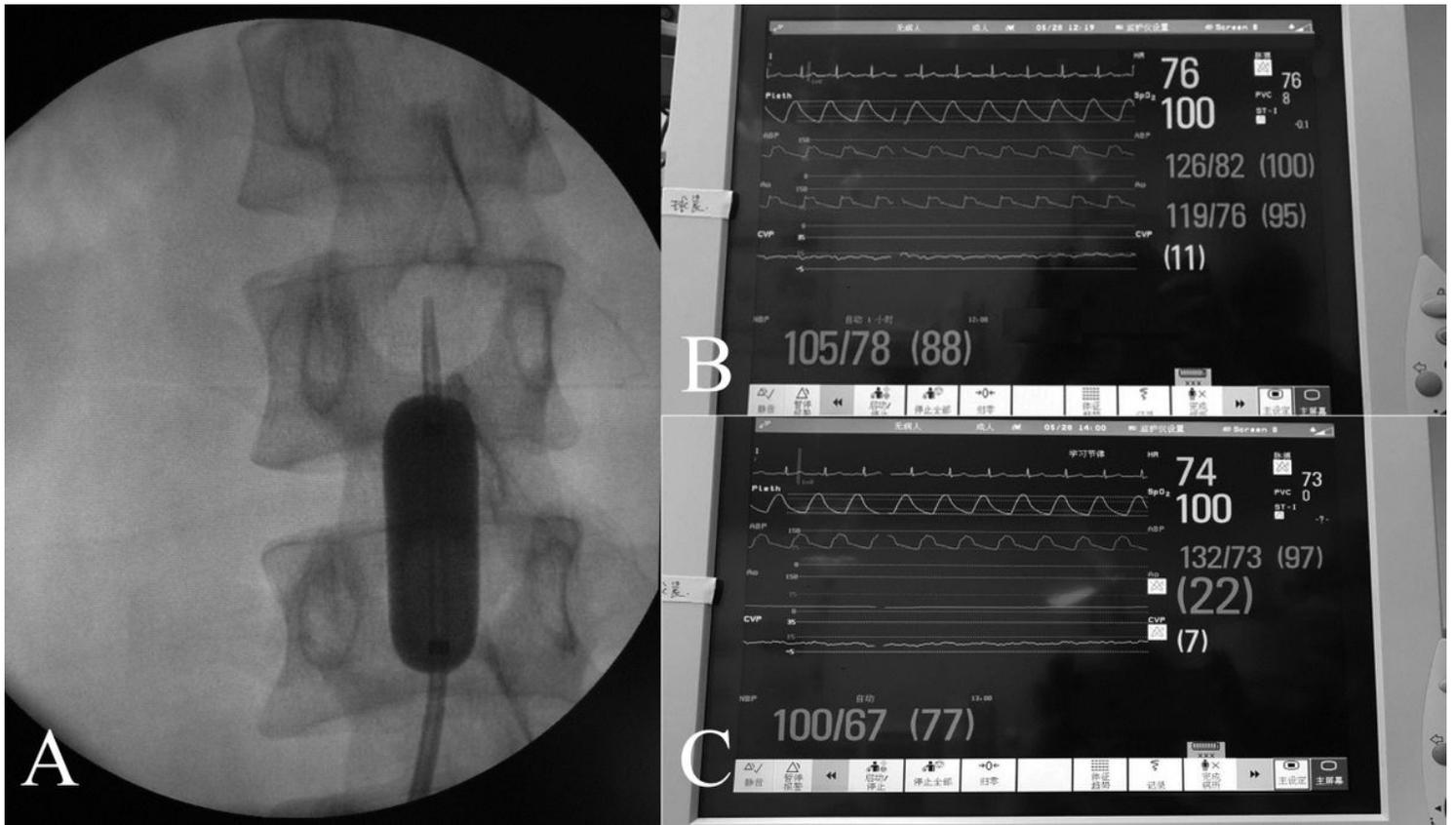
Data are shown as mean  $\pm$  SD, median (interquartile), n (%). \* P<0.05. CRC=concentrate red cell, FFP=frozen fresh plasma. Fluid excess=Fluid infused (including CRC and FFP)-(Blood loss + Urine output)/Body weight. Prolonged hospital stay=Hospital stay longer than 28 days

Table 2. Demographic, surgical, anesthetic data and clinical outcomes of patients receiving aortic occlusion								
	Before PSM				After PSM			
	Fluid excess >38.5 ml/kg (n=111)	Fluid excess ≤38.5 ml/kg (n=167)	Statistical value	P Value	Fluid excess >38.5 ml/kg (n=91)	Fluid excess ≤38.5 ml/kg (n=91)	Statistical value	P Value
Male Gender	56 (50.4%)	92 (55.0%)	0.576	0.464	46 (50.5%)	45 (49.4%)	0.002	1.000
Age (years)	45 ± 15	53 ± 16	4.081	<0.001*	45 ± 13	44 ± 15	0.123	0.903
Height (cm)	164.1 ± 6.2	166.6 ± 6.2	0.63	0.26	164.8 ± 5.3	164.6 ± 5.8	0.356	0.722
Weight (kg)	63.2 ± 6.9	67.6 ± 9.8	0.166	0.434	64.6 ± 5.8	64.3 ± 6.6	0.298	0.766
ASA classification (n)			0.927	0.669			0.444	0.801
Diagnosis (n (%))			0.29	0.865			0.207	0.901
<b>Benign</b>	42 (37.8%)	58 (34.7%)			33 (36.3%)	34 (37.4%)		
<b>Malignant</b>	54 (48.6%)	86 (51.4%)			46 (50.5%)	47 (51.6%)		
<b>Metastatic</b>	15 (13.5%)	23 (13.7%)			12 (13.2%)	10 (10.9%)		
Recurrent tumor (n)	33 (29.7%)	59 (35.3%)	0.354	0.200	26 (28.5%)	34 (37.4%)	1.591	0.270
Total En bloc (n)	8	0	2.267	0.132	2 (2.2%)	3 (3.3%)	0.031	1.000
Duration of surgery (min)	294 (76)	190 (65)	-2.801	<0.005*	200 (70)	190 (70)	-1/456	0.145
Duration of anesthesia (min)	303 ± 65	265 (62)	-4.028	0.000*	290 (75)	276 (76)	-0.908	0.364
Duration of aortic occlusion (min)	70 (30)	60 (30)	-2.273	0.023*	65 (40)	65 (40)	-0.207	0.836
Hemoglobin before surgery(g/L)	102 ± 7.5	103 ± 7.6	-1.08	0.281	101 ± 7.5	103 ± 7.2	-1.454	0.148
Hemoglobin after surgery (g/L)	83.4 ± 5.0	83.4 ± 5.1	0.0	1.0	83.4 ± 5.0	83.2 ± 5.1	0.190	0.850
Blood loss (ml)	1200 (1200)	1100 (700)	-2.704	0.038*	1100 (1000)	1100 (1150)	-0.501	0.617
CRC infused (ml)	780 (520)	520 (260)	-4.719	0.000*	780 (520)	520 (260)	-3.069	0.002
FFP infused (ml)	600 (600)	400 (400)	-5.697	0.000*	600 (400)	400 (400)	-2.757	0.006

Crystalloid/colloid (ml)	3820 (1160)	2780 (800)	-9.795	0.000*	3740 (1200)	2820 (840)	-7.393	0.000*
Fluid excess (ml/kg)	47.5 (17)	28.6 (12)	-14.119	0.000*	46 (15)	30 (11)	-11.625	0.000*
Complications								
<b>Excessive bleeding (n(%))</b>	32	29	5.116	0.027*	21	20	0.031	1.000
<b>Debridement (n (%))</b>	32(28.8%)	24 (14.3%)	8.664	0.004	24 (26.3%)	12 (13.1%)	4.986	0.04*
<b>ICU (n (%))</b>	8 (7.2%)	9 (5.3%)	0.384	0.612	5 (5.4%)	5 (5.4%)	0.000	1.000
<b>CSF leak (n (%))</b>	8 (7.2%)	5 (2.9%)	2.665	0.146	5 (5.4%)	1 (1.1%)	2.758	0.211
<b>Thrombosis (n(%))</b>	6 (2.2%)	2 (2.6%)	0.0528	0.818	2 (2.2%)	2 (2.2%)	0.000	1.000
Length of Stay (days)	21 (15)	18 (10)	-3.987	<0.001*	21 (14)	20 (13)	-0.432	0.666
<b>Prolonged hospital stay (n(%))</b>	49 (17.6%)	5 (6.4%)	5.794	0.016*	21 (23.1%)	15 (16.2%)	1.247	0.352

Data shown in mean  $\pm$  SD, median (IQR), n (%). \* P<0.05. PSM=propensity score match, propensity score 0.02. The propensity score was calculated by logistic regression analysis using the following covariates: age, gender, height, body weight, ASA grade, duration of aortic occlusion, duration of surgery and duration of anesthesia, pathology and blood loss. CRC=concentrate red cell, FFP=frozen fresh plasma. Fluid excess=Fluid infused (including CRC and FFP)-(Blood loss + Urine output)/Body weight. CSF=cerebrospinal fluid. Prolonged hospital stay=Hospital stay longer than 28 days

## Figures



**Figure 1**

Intra-aortic balloon application. A. Intra-aortic balloon filled with contrast agent. B. The aortic waveform on the monitor screen before IABO. C. The waveform showing the occlusion pressure of the aorta when the balloon was filled with normal saline.

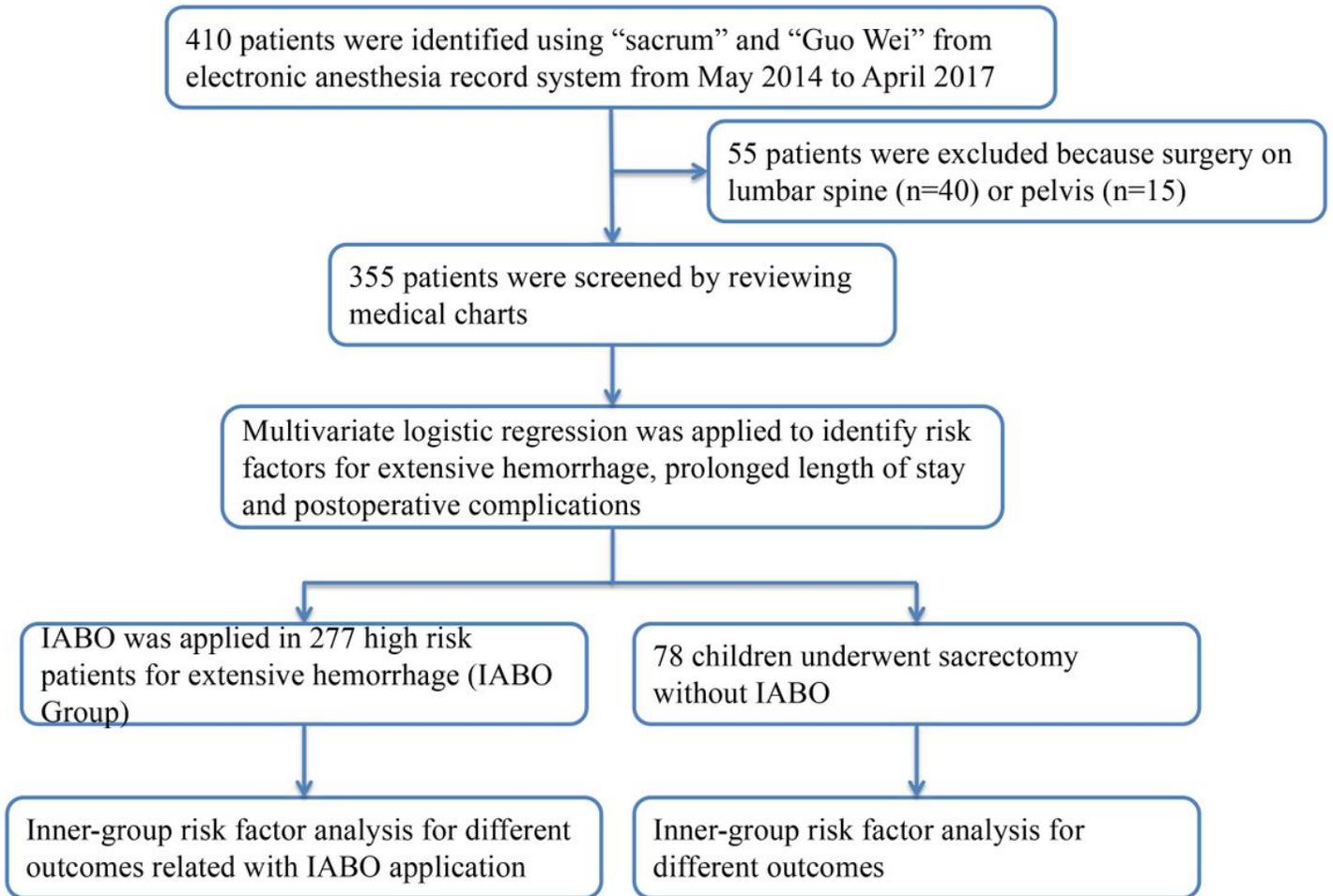
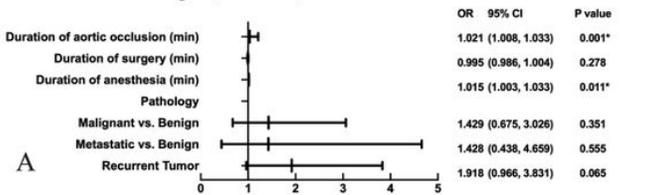


Figure 2. Trial profile  
IABO= Intra Aortic Balloon Occlusion

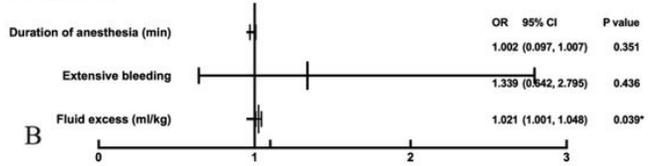
**Figure 2**

Trial profile.

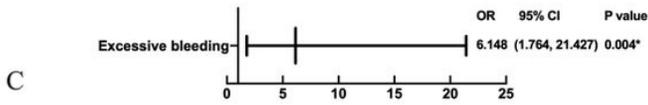
**Extensive Hemorrhage (>2000 ml)**



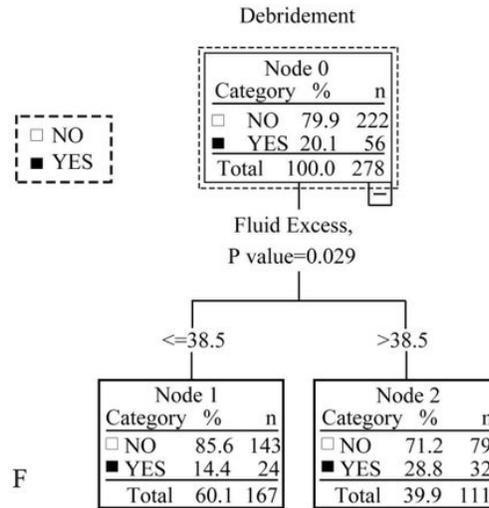
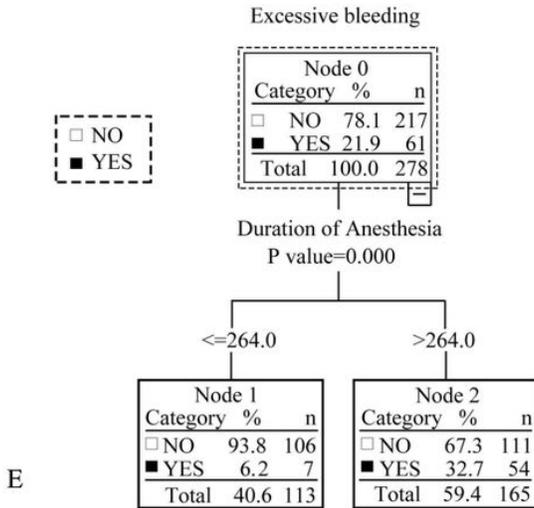
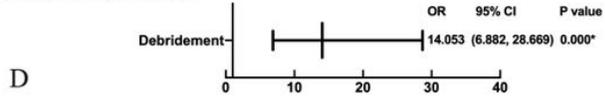
**Debridement**



**ICU Admission**



**Prolonged length of stay**



**Figure 3**

Logistic regression and decision tree analysis for complications related with sacrum resection. A. Multivariate regression for extensive hemorrhage (>2000 ml). B. Multivariate regression for postoperative debridement. C. Risk factor for ICU admission. D. Risk factor for prolonged hospital stay. E. Decision tree analysis of Excessive hemorrhage. F. Decision tree analysis for postoperative debridement.

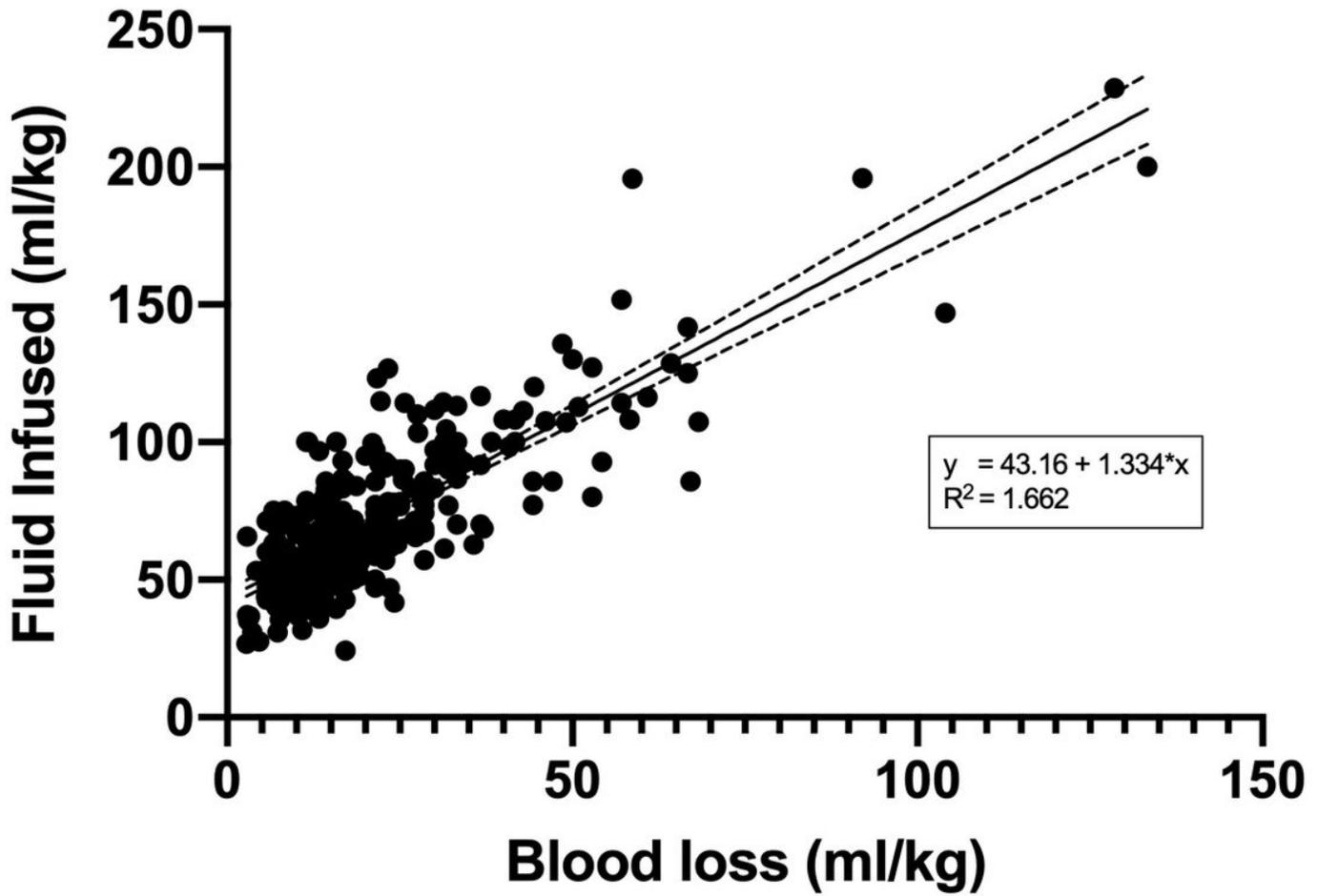


Figure 4

The linear correlation between intraoperative blood loss and fluid excess. Fluid excess was calculated as volume infused (crystalloid, colloid, CRC and FFP), minus blood loss and urine output, divided by body weight (kg).

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Sacrum.mov](#)