Research Square

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Combined, Converted, and Prophylactic Use of Resuscitative Endovascular Balloon Occlusion of the Aorta for Severe Torso Trauma: A Retrospective Study

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Research Article

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Abstract

Background: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is used as an intra-aortic balloon occlusion method in Japan; however, the protocols for its effective use in different pathological conditions remain unclear. This study aimed to summarise the strategies of REBOA use in severe torso trauma.

Methods: Twenty-nine cases of REBOA for torso trauma treated at our hospital over 5 years were divided into the shock (n=12), cardiopulmonary arrest (CPA) (n=13), and non-shock (n=4) groups. We retrospectively examined patient characteristics, trauma mechanism, injury site, severity score, intervention, survival rates at 24 hours, and intervention details in each group.

Results: In the shock group, 9 and 3 patients survived and died within 24 hours, respectively; time to intervention (56.6 vs 130.7 min, p=0.346) and total occlusion time (40.2 vs 337.7 min, p=0.009) were both shorter in surviving patients than in the casualties. In the CPA group, 10 patients were converted from resuscitative thoracotomy with aortic cross-clamp (RTACC); a single patient survived. Four patients in the non-shock group survived, having received prophylactic REBOA.

Conclusions: The efficacy of REBOA for severe torso trauma depends on patient condition. In the shock group, time to intervention and total occlusion time correlated with survival. The use of REBOA with definitive haemostasis and minimum delays to intervention may improve outcomes. Patients with CPA are at a high risk of mortality; however, conversion from RTACC may be effective in some cases. Prophylactic intervention in the non-shock group may help achieve immediate definitive haemostasis.

Background

Resuscitative endovascular balloon occlusion of the aorta (REBOA) was developed in 1953 by Edwards et al. for use in abdominal aortic aneurysm surgery.[1] In 1989, Gupta et al. launched its clinical application to intra-abdominal bleeding due to trauma.[2] In Japan, the first clinical application of the aortic occlusion catheter for bleeding control in blunt abdominal trauma was reported in 1998; since then, it has been used in scenarios involving intra-aortic balloon occlusion (IABO), among others; however, there is little evidence regarding the efficacy of this practice. In the United States, REBOA was reintroduced by Stannard et al. in 2011, followed by several reports on its clinical efficacy. Recently, several studies, including systematic reviews,[4-7] have shown the superiority of REBOA over resuscitative thoracotomy with aortic cross-cramp (RTACC), performed for the same purpose.

Materials And Methods

The present study aimed to examine novel strategies of REBOA use for severe torso trauma. We included 29 patients with torso trauma treated with REBOA between 2016 and 2021 at our facility. The mean age was 56.6 years, and 19 patients were male. The patients were divided into shock (n=12), cardiopulmonary arrest (CPA) (n=13), and non-shock (n=4) groups (Fig. 1). Shock was defined as systolic blood pressure levels <90 mmHg or shock index >1 point at the time of arrival or at the scene and requiring an intervention other than blood transfusion alone. CPA was defined as CPA at the time of arrival or within a short time after arrival. Non-shock status was defined as achieving stability after a transfusion between the time of arrival and the start of intervention, and where the patient did not progress to shock. Informed consent was obtained from all participants.

Data acquisition and statistical analysis

Patients were divided into mortality and survival groups at 24 hours. The following variables were compared between the groups: demographic and clinical characteristics, trauma mechanism, trauma score (abbreviated injury score calculation was based on AIS98 until 2018, and AIS2008 after 2019), intervention type and context (time to intervention, total occlusion time in the shock group, percentage of conversion to REBOA from RTACC in the CPA group, and percentage of inflation needed in the non-shock group). Values are presented as the mean ± standard error. Data were analysed using the Mann–Whitney U test. Statistical analyses were performed using GraphPad Prism 7 software (GraphPad Inc., San Diego, CA, USA), and statistical significance was set at p-values of <0.05.

Results

The characteristics of the patients in the shock group are presented in Table 1. At 24 hours, 9 and 3 patients were alive and dead, respectively. Injury severity score (ISS) was not significantly different between the groups (26±4.9 vs 39±12.2, ns); however, revised trauma score (RTS) and probability of survival were significantly lower in the patients who died than in those who survived (5.74±0.43 vs 2.62±0.36, p=0.009 and 0.70±0.09 vs 0.14±0.07, p=0.03 respectively). The time to intervention (from REBOA inflation to intervention start) was shorter in the patients who survived than in those who died (56.6 min vs 130.7 min, p=0.346 (Fig. 2). Total occlusion time was significantly shorter in the patients who survived than in those who died (40.2 vs 337.7 min, p=0.009) (Fig. 3).

Table 1. Characteristics of the patients in the shock group

	Survived for 24 h (n=9)	Died in 24 h (n=3)	p-value
Sex (male : female)	5 : 4	1 : 2	
Age (years)	54.7±10.5	53.3±16.2	>0.999
Mechanism	MVA 7	Fall 2	
	Compression 1	MVA 1	
	Stab 1		
Injury site	Thoracic organ 1	Thoracic organ 1	
	Abdominal organ 6	Abdominal organ 2	
	Pelvic fracture 4	Pelvic fracture 1	
	Extremity 1		
ISS	26±4.9	39±12.2	0.259
RTS	5.74±0.43	2.62±0.36	0.009*
Ps	0.70±0.09	0.14±0.07	0.03*
Intervention	Operation 2	Operation+IVR 3	
	IVR 7		
Time to intervention (min)	56.6±13.4	130.7±63.2	0.346
Total occlusion time (min)	40.2±12.5	337.7±105.4	0.009*

IVR, interventional radiology; MVA, motor vehicle accident; ISS, injury severity score; RTS, revised trauma score; Ps, probability of survival

Values are presented as mean ± standard error of the mean. $p<0.05$ was considered significant (*).

The characteristics of the CPA patients are presented in Table 2. In each case, the severity of injury was high, and the probability of survival was low. RTACC was used in 10 patients, including a patient who survived for 24 hours, and REBOA was used as a conversion from RTACC. The surviving patient was a male in his early thirties injured by a fall. He underwent CPA during transport. RTACC was performed immediately after admission to the emergency department and the return of spontaneous circulation was achieved within 7 minutes. Focused assessment with sonography for trauma findings were positive and emergent laparotomy was performed. After controlling the bleeding from the mesentery, REBOA was inserted from the right femoral artery and placed in Zone I with manual confirmation in the chest cavity. Subsequently, the chest wound was closed using thoracic drainage. REBOA was managed with partial occlusion and could be deflated with a total occlusion time of 68 min due to stable circulation.

Table 2. Characteristics of patients in the cardiopulmonary arrest group

	Survived for 24 h (n=1)		Died in 24 h (n=12)	
Sex (male : female)	1 : 0		9 : 3	
Age (years)	31		56.1±6.2	
Mechanism	Fall	1	MVA	10
			Fall	1
			Compression	1
Injury site	Thoracic organ	1	Thoracic organ	8
	Abdominal organ	1	Abdominal organ	6
	Pelvic fracture	1	Pelvic fracture	3
			Extremity	1
ISS	41		38±3.6	
RTS	0		2.58±0.74	
Ps	0.02		0.22±0.07	
Intervention	Operation	1	Operation	2
			IVR	1
			Operation + IVR	1
			Not achieved	8
Convert from RTACC	1 in 1 (100%)		9 in 12 (75%)	

IVR, interventional radiology; MVA, motor vehicle accident; ISS, injury severity score; RTS, revised trauma score; Ps, probability of survival

Values are presented as mean ± standard error of the mean

The characteristics of non-shock patients are presented in Table 3. All four patients survived for 24 hours with prophylactic care; one patient required inflation during treatment. This patient was a female in her mid-eighties injured by MVA and transported to our hospital by a helicopter emergency medical service. At the emergency department, she was not in shock, presenting with a heart rate of 68 beats/min and blood pressure of 100/62 mmHg; however, radiography and computed tomography findings showed pelvic fracture and extravasation of contrast, and IVR (transcatheter arterial embolization; TAE) was implemented. Preoperatively, prophylactic REBOA was inserted through the left femoral artery, and IVR was performed through the right femoral artery. TAE was successfully completed with temporary inflation of the REBOA to maintain hemodynamic stability.

Table 3. Characteristics of the patients in the non-shock group (all patients survived beyond 24 h)

	Values
Sex (male : female)	3 : 1
Age (years)	71±5.4
Mechanism	MVA 2
	Fall 2
Injury site	Pelvic fracture 4
	Extremity 1
ISS	26.3±8.0
RTS	7.33±0.23
Ps	0.76±0.11
Intervention	Operation 1
	IVR 2
	Conservative 1
Inflation needed (%)	1 in 4 (25%)

IVR, interventional radiology; MVA, motor vehicle accident; ISS, injury severity score; RTS, revised trauma score; Ps, probability of survival

Values are presented as mean ± standard error of the mean.

Discussion

REBOA is an endovascular approach to aortic occlusion that aims to prevent cardiac arrest in cases of severe haemorrhagic shock. It is less invasive than RTACC, which may be used for the same purpose, and it can be used in interventions that require precision, including partial or intermittent occlusion. However, REBOA may be more time-consuming than RTACC. These aspects of both procedures need to be considered to identify the approach that is most likely to yield desirable patient outcomes.

Previously, Inoue et al. performed a propensity score-based analysis of the Japan Trauma Data Bank to evaluate mortality rates associated with REBOA, [8] which were found to be higher than those associated with non-REBOA interventions. The median time required from hospital arrival to intervention in the REBOA group was 97 minutes. This finding suggests that the use of REBOA in situations where it is not indicated and the lack of systems that enable to rapidly perform definitive haemostasis may have worsened the outcomes of patients undergoing REBOA. These patterns may reflect the specific Japanese context, which lacks standardised protocols for the use REBOA across trauma centres.

The 31st Annual Meeting of the Japanese Association for the Surgery of Trauma in 2018 resulted in two sets of guidelines on the adaptation and utilisation of IABO/REBOA for trauma care. The first one states that IABO/REBOA should not be implemented for the sole purpose of obtaining a computed tomography scan, but to shorten the time to controlled bleeding. The second one states that the aim of employing IABO/REBOA is to prevent cardiac arrest.[8] Matsumoto et al. reported that RTACC is more frequently performed in patients with thoracic trauma than in those without thoracic trauma in Japan.[9] Matsumura et al. performed a study based on a Japanese multi-institutional dataset, showing that partial occlusion, conversion from thoracotomy, and timely but shorter occlusion might be related to successful hemodynamic stabilisation and improved survival.[10] Early recognition of patients who may require REBOA following early arterial access may help improve outcomes.[11]

This study showed that the time to intervention and total occlusion time were correlated with 24-hour survival rates in the shock group, suggesting that prolonged shock and coagulopathy due to delayed haemostatic intervention and the progression of lower organ ischaemia due to a delay in deflation of REBOA may worsen outcomes. Factors associated with survival may include shortening the time to the start of haemostatic intervention and early deflating of REBOA, i.e., immediate definitive haemostasis.

Our previous study (n=14) showed that blood pressure increased significantly with REBOA use without affecting outcomes. Meanwhile, reduced transfusion volume and total occlusion time (i.e., immediate definitive hemostasis) were factors associated with survival.[12] In addition, another study (n=46) suggested that REBOA may be effective in the treatment of shock, either combined with haemostatic intervention for hemodynamic stabilisation or by achieving temporary hemostasis, and that prior insertion of REBOA (prophylactic use) may be effective if the patient is not in shock at the time of admission (unpublished data). In a case reported in Japan, intraoperative bleeding was controlled and a good surgical field was secured by the combined use of REBOA with haemostatic laparotomy, resulting in improved rates of hemostasis completion and survival.[13] Reports from abroad, in which proximal control with REBOA was useful before intraoperative retroperitoneal hematoma exploration, support these findings.[14,15]

In summary, for traumatic haemorrhagic shock, it is important to combine the use of REBOA with immediate haemostatic intervention to achieve hemostasis first; alternatively, REBOA may be performed followed by hemostasis, provided delays can be avoided. The time window is approximately <1 h, based on the present findings; delays of >1 h to obtain a computed tomography scan or due to REBOA-associated factors may be detrimental to outcomes.

In the CPA group, the severity of injury and mortality rates were high; however, in some cases, the use of RTACC (conversion to REBOA) was effective. Conversion to REBOA helps reduce lower organ ischaemia, prevent hypothermia, and reduce chest wall bleeding (associated with thoracotomy) by shifting from complete occlusion by RTACC to partial or intermittent occlusion by REBOA, while ensuring the rapidity and certainty of RTACC. The REBOA handbook, the first official textbook in Japan, reports the usefulness of REBOA.[16] In addition, the position of the catheter tip can be confirmed visually and by palpation under thoracotomy. A combination of interventions may expand the range of protocols available and improve patient outcomes. RTACC should be performed promptly for cases of impending cardiac arrest, and early conversion to REBOA may improve outcomes in some cases. The combined and conversion approaches are consistent with the original purpose of REBOA (resuscitative use by physiological indication).

In contrast, prophylactic REBOA use was helpful in some cases in the non-shock group. Prophylactic use may help achieve rapid definitive hemostasis by stabilising hemodynamic and maintaining a good field of view by controlling bleeding. Previous case reports from Japan have shown the benefits of prophylactic use in patients at high risk of major bleeding due to intraoperative manipulation,[17,18] and those of intraoperative placement for patients with more stable admission physiology.[19] Such a “non-resuscitative use” may seem paradoxical, given the name of REBOA, but it may lead to good outcomes.

Overall, REBOA may be used in different ways, some of which may help improve outcomes, provided great care is executed and the intervention is delivered at the right time. REBOA has been nicknamed the ‘countdown to death’, referring to the risks associated with lower organ ischaemia that increase while temporary hemodynamic stabilisation is achieved; consequently, this approach should be used judiciously. RTACC for the same purpose can be used differently or in combination with REBOA, as required; however, the timing of intervention remains paramount to outcomes.

This study, however, is subject to a limitation owing to its small sample size because it is a single-centre study and the use of REBOA is generally limited to severe cases including CPA. Although it is difficult to conduct prospective studies on REBOA, it is desirable to collect data and provide evidence through multicentre studies in Japan.

Conclusion

The effective use of REBOA for severe torso trauma depends on patient condition; a combined approach with immediate hemostasis may benefit the shock group, while conversion from RTACC may benefit the CPA group, and prophylactic use may benefit the non-shock group.

Abbreviations

CPA, Cardiopulmonary arrest

IABO, Intra-aortic balloon occlusion

REBOA, Resuscitative endovascular balloon occlusion of the aorta

RTACC, Resuscitative thoracotomy with aortic cross-clamp

ISS, Injury severity score

RTS, Revised trauma score

Ps, probability of survival

Declarations

Ethics approval and consent to participate

In accordance with the privacy policy of Aichi Medical University Hospital, we have posted a notice stating that information that could identify the study participants may be deleted and used in conference presentations and paper presentations for research purposes. Informed consent was obtained from all participants.

Consent for publication

Same as above.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None.

Author's contributions

YK, HM, TT, ST, MH, and YK participated in the treatment of patients and data collection. TI analysed the data and drafted the manuscript. DO and MT participated in the design of the study and helped to draft the manuscript. NT supervised the study.

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Figures

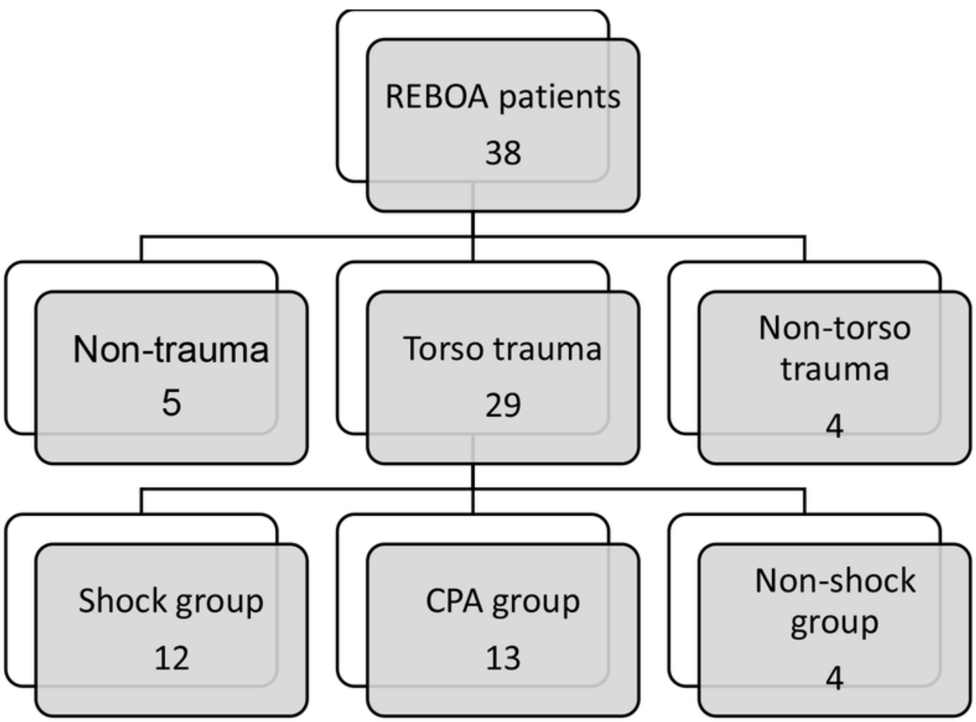

Figure 1

Patients who underwent REBOA in this study

A total of 29 patients with torso trauma were divided into the shock (n=12), cardiopulmonary arrest (CPA) (n=13), and non-shock (n=4) groups.

REBOA, resuscitative endovascular balloon occlusion of the aorta

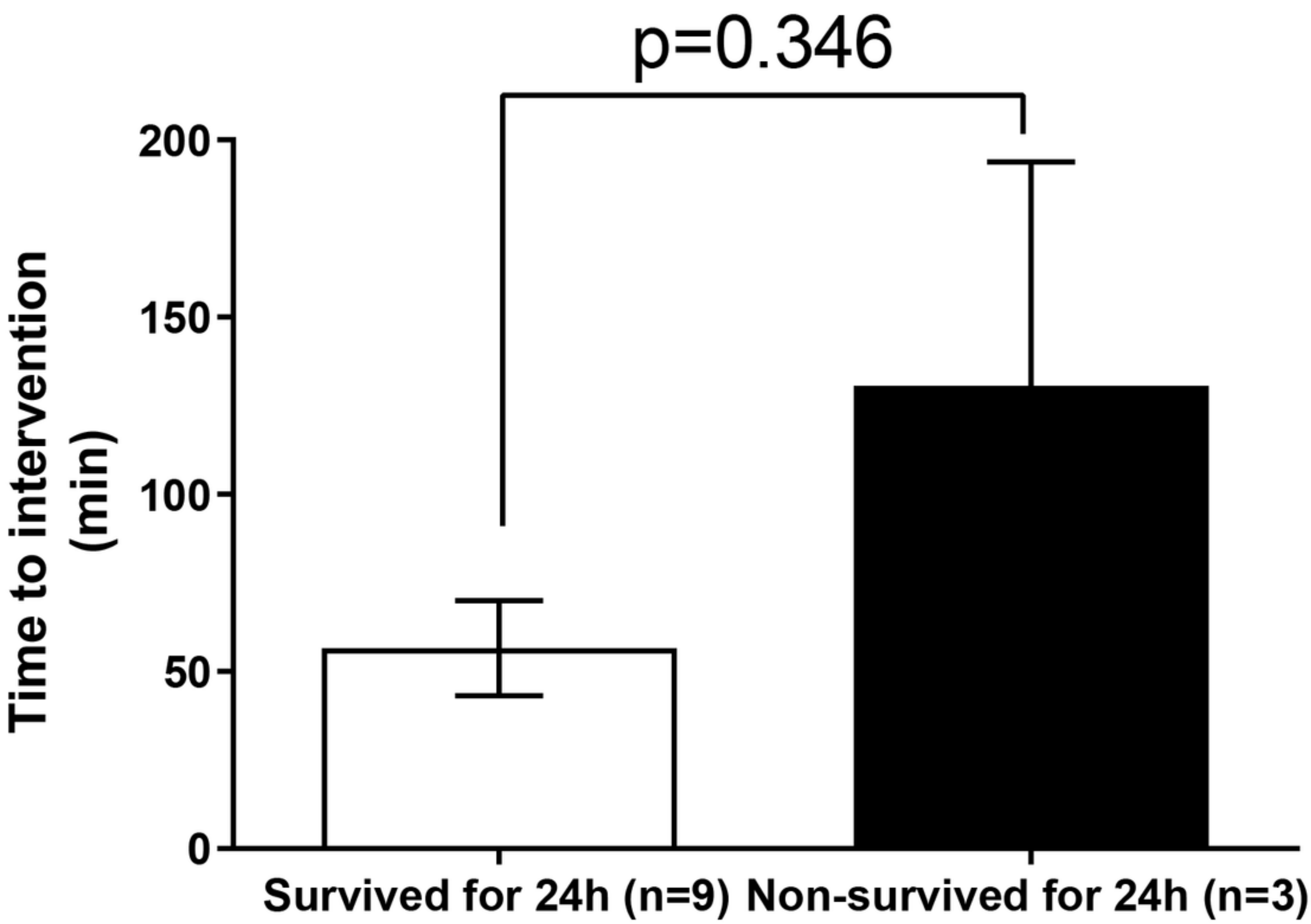

Figure 2

Time to intervention

Time from REBOA inflation to intervention start was shorter in the patients who survived than in those who died (56.6 min vs 130.7 min, p=0.346).

REBOA, resuscitative endovascular balloon occlusion of the aorta

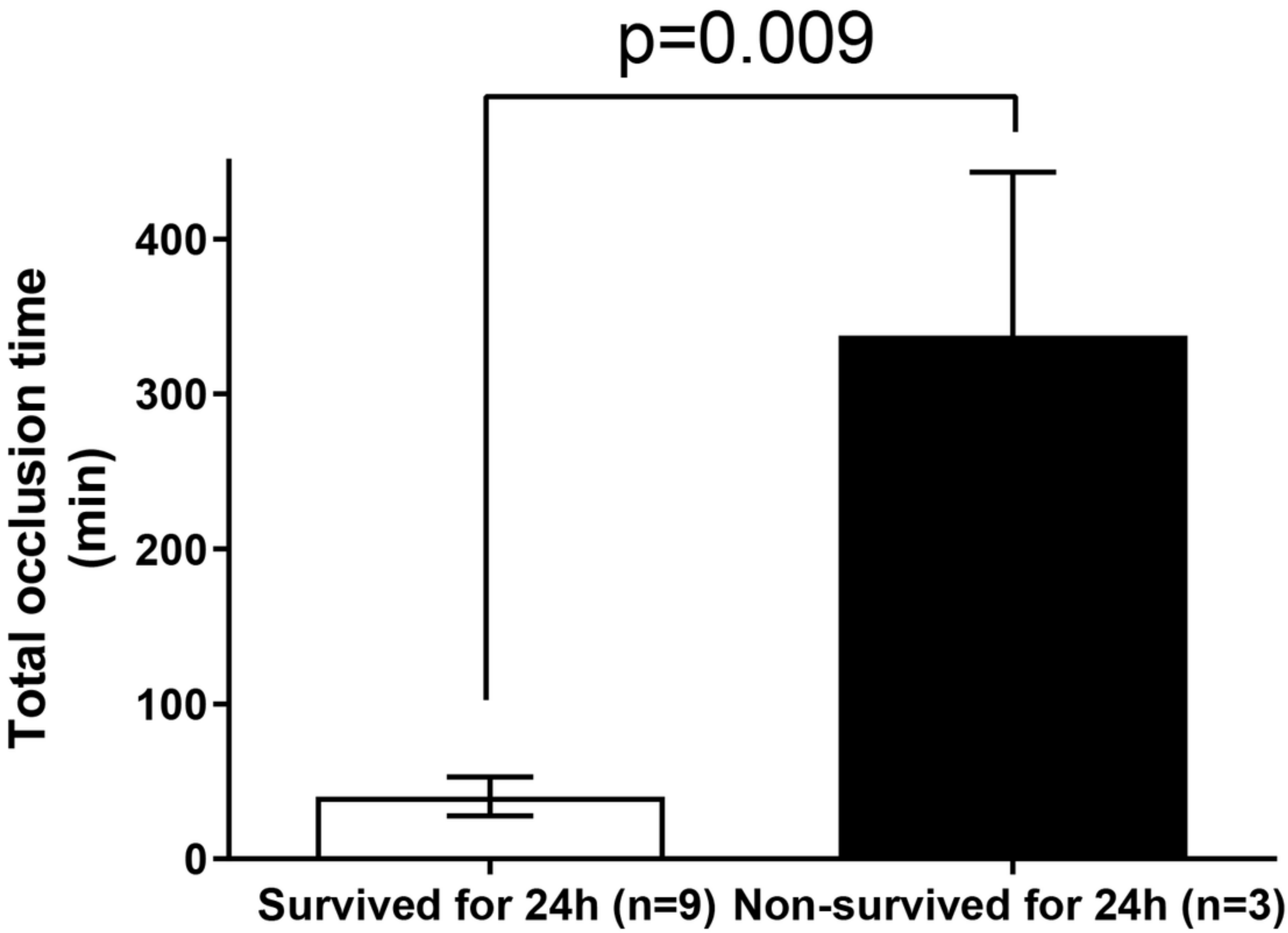

Figure 3

Total occlusion time

Total occlusion time was significantly shorter in the patients who survived than in those who died (40.2 vs 337.7 min, p=0.009).