How many patients could benefit from REBOA in prehospital care? A retrospective study of patients rescued by the doctors of the Paris fire brigade

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ABSTRACT

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Received 15 January 2018 Revised 29 January 2018 Accepted 1 February 2018 Published Online First 27 February 2018

Introduction Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a technique to control haemorrhage by placing a retrograde catheter in an artery and inflating a balloon at its tip. This retrospective study aimed to evaluate the proportion of injured people who could potentially have benefited from this technique prior to hospitalisation, including on the scene or during transport.

Methods A retrospective analysis was conducted of all patients with trauma registered in the Paris Fire Brigade emergency medical system between 1 January and 31 December 2014. Inclusion criteria included all patients over 18 years of age with bleeding of supposedly abdominal and/or pelvic and/or junctional origin, uncontrolled haemorrhagic shock or cardiac arrest with attempted resuscitation.

Results During this study period, a total of 1159 patients with trauma (3.2%) would have been eligible to undergo REBOA. Death on scene rate was 83.8% (n=31) and six patients had a beating heart when they arrived at the hospital. Ten out of the 37 patients had spontaneous circulatory activity. Among them, four people died on the scene or during transport. Thirty-six out of 37 patients were intubated, one benefited from the use of a haemostatic dressing and one benefited from a tourniquet.

Conclusions REBOA can be seen as an effective non-surgical solution to ensure complete haemostasis during the prehospital setting. When comparing the high mortality rate following haemorrhage with the REBOA's rare side effects, the risk-benefit balance is positive. Given that 3% of all patients with trauma based on this study would have been eligible for REBOA, we believe that this intervention should be available in the prehospital setting. The results of this study will be used: educational models for REBOA balloon placement using training manikins, with an ultimate aim to undertake a prospective feasibility study in the prehospital setting.

INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a concept first utilised during the Korean War.¹ It aims at occluding the aorta upstream of an abdominal, pelvic or junctional, bleeding site by inflating a small balloon introduced in the femoral artery by retrograde catheterisation. So far, REBOA has been used in trauma centres, but it was used for the first time in prehospitalisation by the London Helicopter Emergency Medical Service (HEMS) (aka London's air ambulance) in

Key messages

- Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a method to control haemorrhage by placing a retrograde catheter in the artery and inflating a balloon at its tip.
- REBOA can potentially benefit on several patients in prehospital medicine or battlefield medicine.
- Indications include traumatic haemorrhagic shock or cardiac arrest by exsanguination, when the bleeding is from abdomen, pelvis or junctional areas.
- This retrospective study evaluated the proportion of injured people who could have benefited from this technique before their hospitalisation.

2016.² Since then, several civilian and military teams around the world have been working on the interest and the feasibility of installing the device in the field.³

Unlike London's air ambulance teams, French prehospital emergency physicians are able to install arterial catheters but do not have REBOA devices. The French therapeutic strategy for the management of a patient with severe trauma includes pelvic immobilisation using a girdle, permissive hypotension and rapid transport to a trauma centre. Despite these interventions, mortality from major trauma remains high. This retrospective study aimed to evaluate the proportion of injured people who could potentially have benefited from this technique prior to hospitalisation, including on the scene or during transport.

METHODS

Study design and setting

A retrospective analysis was conducted of all patients with trauma registered in the Paris Fire Brigade emergency medical system between 1 January and 31 December 2014. The patient demographic includes Paris and its suburbs, comprising 124 cities and towns covering an area of 762 sq km. The Paris Fire Brigade emergency medical system utilises a two-tier response system. The first is a basic life support tier served by 250 teams of 3-5 professional rescuers deployed in 80 stations. The second is an advanced cardiac life support tier served by six ambulances armed by the Paris fire

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To cite: Thabouillot O, Bertho K, Rozenberg E, et al. J R Army Med Corps 2018;164:267-270



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brigade whose each team comprises an emergency physician, a nurse and a driver.

The protocol used for REBOA comprises a balloon inflated in the lumen of the aorta in order to occlude it, partially or totally, continuously or intermittently. The insertion of the balloon is carried out in a retrograde manner, by puncture of the femoral artery followed by a Seldinger method. The balloon can be inflated in two different zones. Zone 1 is located between the left subclavian artery and the superior mesenteric artery in case of abdominal bleeding. Zone 3 is located between the lower mesenteric artery and the iliac bifurcation for pelvic or junctional bleeding. The use of REBOA in Zone 1 in particular is relatively easy, because the anatomical landmarks can dispense with the use of ultrasonography or fluoroscopy and because it stops bleeding from abdomen and pelvic or junctional injury.

Study population

Eligibility criteria for placement of REBOA in this study period comprised the following:

- Bleedings of supposedly abdominal and/or pelvic and/or junctional origin.
- Uncontrolled haemorrhagic shock, as defined by a systolic blood pressure of less than 90 mm Hg.
- Five milligrams per hour or more of pressor amine or cardiac arrest due to bleeding in the areas indicated above.
- Patients over 18 years of age.

Data collection

Within the Paris Fire Brigade emergency medical system, data are collected using a medical intervention form completed by the physician who was in charge of the patient before hospitalisation. Data fields include age at injury, gender, mechanism of injury, clinical parameters, treatments, intervention delays and any particular events occurring during the intervention.

Statistics

The estimators were the median (IQR) for quantitative data and the rate for qualitative data. An exact Fisher's test was used to compare percentages, with a significance level of < 0.05.

RESULTS

During this period, a total of 37/1159 (3.2%) patients with trauma met the inclusion criteria. Only six patients were still ş alive when they arrived at the hospital (figure 1). The median age was 44 years (range 32–58), of which 75.6% were male. Four copyright broad types of circumstances were identified which resulted in injuries: fall from great height, n=22 (59.5 %), traffic accident, n=8 (21.6 %), collision with a train, n=4 (10.8 %) and stab wound or gunshot injury, n=3 (8.1 %).

including The locations of injuries for which, following a clinical examination by the on-site physician, REBOA was possibly indicated were: nine (24 %) at the abdominal level, 20 (54 %) at the pelvic level, one (3 %) at the level of femoral artery passage in the inguinal fold for uses related to text and data mining, AI training, and similar technologies and seven (20 %) combined abdominopelvic trauma. The median injury severity score (ISS) was 29 (25-34).

Regarding the on-site treatments, 36 patients out of 37 were intubated, nine underwent from exsufflation or thoracotomy to treat a pneumothorax, one patient received OuikClot haemostatic dressing and one patient had a tourniquet applied.



Figure 1 Flow chart. CPR, cardio pulmonary resuscitation; REBOA, resuscitative endovascular balloon occlusion of the aorta; ROSC, return of spontaneous circulation.

The median cumulated dose of noradrenalin and/or adrenalin administered per hour using a syringe driver and/or as a bolus was 5.5 mg (range 4–7). This dose ranged between 4 and 7 mg among the patients who were admitted alive at the hospital. The median duration between the departure of the ambulance and its arrival at the scene was 7 min (range 5–12). The median time between the start of the ALS team's treatment and the arrival at the trauma centre was 55 (50-62) min. This time included the completion of the resuscitation procedures, the conditioning of the injured person and his transport.

Outcomes

When the ALS team arrived, among five patients with spontaneous circulation, three arrived alive at the hospital. On the 32 patients with CPR in progress when medical team arrived, five had a ROSC and only three arrived alive at the hospital. Among these 10 victims with a cardiac activity, six (60%) were admitted alive to hospital and four died before their admission. Globally, the out-of-hospital death rate was 83.8% (n=31) (figure 1).

DISCUSSION

The aim of this study was to identify patients eligible for prehospital REBOA as part of emergency care delivered by an ALS team in a retrospective cohort of severely injured patients. Utilising the inclusion criteria proposed in this study, 3.2% of patients would have been eligible to undergo REBOA, similar to that reported by Barnard *et al*⁴ (5.4%). Among the inclusion criteria proposed is the prior administration of high dose amine. Recent literature does not report the amine doses which patients could have benefited of before or during REBOA,⁵ but selecting patients on the amine criteria is justified by the fact that REBOA is used as a last resort therapy, when the benefit–risk ratio is in favour of this exceptional technique.

No technique, including pelvic haemostatic bandages, XStat or SAM junctional tourniquet,⁶⁻⁹ is fully effective to treat abdominal bleedings. However, extending the use of REBOA as an out-of-hospital technique could potentially enable clinicians to save time as it is the only currently available treatment ensuring complete haemostasis. In case of hypovolaemia, the cardiac pump may stop because of loss of prime, but placement of REBOA associated with a vascular filling could prime the pump again.

The number of studies reporting the hospital use of REBOA remains limited.¹⁰ ¹¹ Work on REBOA is increasing. Use of REBOA has been associated with a 55 mm Hg (IQR 33–60) increase of blood pressure in a US cohort and with a return to spontaneous circulation in 60% of patients (n=10) who had been in cardiac arrest before REBOA, so we believe in use of REBOA in patient with cardiac arrest in prehospital medicine.¹²

A recent meta-analysis¹³ did not show any advantage of REBOA over resuscitative thoracotomy. However, this may reflect that randomised studies in this field are technically and ethically difficult to achieve.

Regarding the criteria for eligibility to undertake REBOA, the threshold value for systolic blood pressure lower than 90 mm Hg is often used in hospital studies, without mention being made of a dose of amine or amount of prior vascular filling. In the Abe study, 83% of patients who had REBOA placement in the emergency room had been transported by non-medicalised ambulance and only 8.6% had received a vascular filling on arrival at the hospital. This reflects a fundamental difference between the UK and France medical systems, as in the latter all prehospital emergencies have a prehospital doctor present. We thus believe that

when a medical prehospital evaluation is being made, REBOA should be used only in cases where the haemorrhagic shock is not brought under control using filling and pressor amines.

The main limiting factor for prehospital REBOA is its feasibility. Reva *et al* have shown that REBOA can be used in pigs in extreme prehospital conditions or even in a helicopter while in flight.³ Manley *et al* have described four war wounded, highlighting the interest of use of REBOA use by emergency doctors who are not surgeons.¹⁴ The median placement time of REBOA under ultrasound (US) guidance has been estimated at approximately 8 min on humans.¹⁵ This is a relatively short time as compared with the total prehospital care time which, in our cohort, was close to 1 hour. Each of our ALS teams is equipped with a portable US machine allowing the femoral artery to be punctured under US guidance, even in a patient with cardiac arrest.

Regarding the choice of the balloon inflation site, regardless of the location of the suspected lesion, the benefit-risk ratio is in favour of Zone 1 as compared with Zone 3. Indeed, in Zone 1, inflation time is restricted to 40 min in order to limit the ischaemia in non-injured areas, which is compatible with the evacuation times of our emergency system. Moreover, placement of the REBOA is easier in Zone 1 because it does not require to spot the inferior mesenteric artery and the iliac bifurcation under US, as it would be the case in Zone 3. In order to position correctly the REBOA, it is recommended to take half of the length of the sternum as a reference.¹⁶ For interventions in rural areas, when the evacuation time to a trauma centre is longer, the interest of specifically positioning the REBOA in Zone 3 if the bleeding is exclusively pelvic or junctional is justified because the duration of acceptable complete occlusion is 2 hours. The evacuation time is essential to avoid the serious undesirable effects and ischaemic complications that the REBOA could induce on organs and tissue initially not injured, including acute renal insufficiency, digestive ischaemia and acute limb ischaemia. In our population, of the 10 patients who had presented, at one point, a recovery of circulatory activity, four did not arrived alive at the hospital. In the literature, the high mortality rate, as compared with the rare, non-life-threatening side effects shows a benefit–risk ratio in favour of REBOA.¹⁷¹⁸

The strategy used to rescue the victims in out-of-control haemorrhagic shock is limited in out-of-hospital settings, as the physician does not have at his/her disposal the means for haemostasis that can be used by surgeons. Thus, prehospital clinicians must deal with comparatively weaker therapeutic means and get the patient to the trauma centre as quickly as possible. REBOA should not be used as an alternative to the scoop-and-run model. Patients with haemorrhagic shock must always be transported extremely quickly to the hospital and REBOA, especially since its median placement time is short, must be used so that these patients arrive alive at the hospital. In a prehospital system relying on paramedical ambulances possibly reinforced by surgical teams, REBOA is an option just as resuscitative thoracotomy. In a widely medicalised prehospital system like ours, no surgical team is sent to the field. Thus, REBOA is the ultimate opportunity to try to save a moribund patient or to resuscitate a patient in cardiocirculatory arrest. We believe that this device should be used as a rescue device when the death of the patient during the prehospital phase would be almost certain, so that the benefit brought by this device could always be greater than the risk it generates. The median ISS of our series being 29, our cohort seems to be representative of such a population.

In a large urban area such as Paris, although the physical distance to a trauma centre may be short, some factors such as

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traffic jams can lead to significant delays in the evacuation times. Furthermore, the stretcher delay between a victim of an accident on the public highway, directly near the ambulance, and a victim on a construction site, in a station, or in an inner courtyard, is very different and much longer for the latter.

The main methodological limitation of our study is its retrospective nature. It is always more difficult to correctly evaluate the indications of a system when it is not part of the proposed therapeutic armamentarium. In addition, the manual entry of the data fields could have underestimated or overestimated the number of patients eligible for REBOA.

Our study is the first to state a hypothesis regarding the eligibility criteria for the use of REBOA so that the number of subjects retrospectively eligible could be evaluated. REBOA currently appears as the unique way to efficiently keep under control the damages in the out-of-hospital settings for doctors who cannot perform rescue thoracotomy. This study will be followed by studies on manikins, then by prospective studies which could, if conclusive, lead to the development of REBOA in the French prehospital system.

 ${\rm Contributors}~{\rm OT}$ and KB are the main authors. All the other authors help to collecting data and review.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

 $\ensuremath{\textcircled{O}}$ Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2018. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

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