Original Article

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Use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) in Trauma Patients in French Level-1 Trauma Centers: A National Survey

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Background: The goal of the present national survey was to describe the practices and use of resuscitative endovascular balloon occlusion of the aorta (REBOA) in France in level-1 trauma centers.
Methods: Between January and December 2023, the ACUTE SFAR (Société Française d'Anesthésie et de Réanimation) committee sent a numeric survey to each French level-1 trauma center. This survey was focused on REBOA in trauma management including: use, protocol (indications, placement, aortic occlusion durations), aortic occlusion location (Zone 1/Zone 3), partial occlusion (pREBOA), device characteristics, operator, specific complications.
Results: Among the 41 French level-1 trauma centers, 18 (44%) had incorporated REBOA in their algorithm. In 2022, 78% (14/18) of these centers had experienced between 1 and 5 REBOA placements, 11% (2/18) between 6 and 10, and 6% (1/18) 10 or more placements. The frequency of REBOA procedures increased with the duration of REBOA availability at the center. A protocol for REBOA placement was present in 28% (5/18) of centers. An anesthesiologist-intensivist was the operator in 50% (9/18), a surgeon in 28% (5/18), and a radiologist in 22% (4/18) of centers. The proportion of centers using REBOA in Zone 1 was 39% (7/18), and pREBOA 33% (6/18). The maximum duration of complete aortic occlusion was specified in 50% of centers for Zone 1 and 78% for Zone 3.
Conclusions: Use of REBOA is modestly spread among the French trauma centers, and in less than half of centers. Specific protocols are present. Anesthesiologist-intensivists are the operators in only half of these centers.

Keywords: *Anesthesiologist; Aortic Occlusion; Bleeding Control; Hemorrhagic Shock; Trauma Management*

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INTRODUCTION

The management of severe trauma casualties is a significant public health concern in most countries. Uncontrolled bleeding remains responsible for early death in nearly 10% of traumatic patients [1]. Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an emergency procedure used to achieve an abdominal intra-aortic occlusion for hemodynamic unstable trauma patients awaiting life-saving management [2]. Data have been increasingly published since the introduction of REBOA by Hughes [3]. The integration of REBOA these past 10 years has offered a deep change of view on the acute management of bleeding trauma patients. With a REBOA placement upon hospital admission, the duration

of active bleeding ends with the aortic occlusion, which differs from management without REBOA, where the time required for hemostatic procedures must be added [4–6]. This difference is particularly interesting in countries in which surgeons are not the designated physicians to manage first-line trauma patients upon hospital admission [4].

In France, severe trauma patients are directed from the trauma scene towards regional level-1 trauma centers based on prehospital medical team reports and severity clinical criteria [7]. In most of these centers, anesthesiologist-intensivists are the designated physicians to provide immediate care upon admission. Because of their skills in many fields, such as ultrasonography or percutaneous vascular catheter insertion, the REBOA device could be an interesting tool in order to limit incompressible delays in the presence of hemodynamic instability or to the need to call the appropriate surgeon or organize a hemostatic intervention [8,9]. However, several concerns still exist among French trauma experts, making the place of REBOA unclear in the French trauma system. The discussions between these French trauma experts suggest that REBOA has not been widely adopted in the trauma centers across France. Furthermore, no study has comprehensively described the use of REBOA on a national scale.

The main objective of the present work was therefore to provide an up-to-date overview of REBOA use in French level-1 trauma centers. A secondary objective was to characterize and detail the clinical practices related to REBOA in centers with experience in this procedure.

METHODS

Study Design

A prospective study was conducted in France using a declarative survey between January 2023 and December 2023. A link to an open *Google Form Internet Survey* was sent by email to the referents of all medical teams in each of the 41 level-1 trauma centers (Supplementary File 2). All participants also received information about the survey objectives in the preface of the questionnaire. The design of the present study was clearly indicated in order to obtain informed consent. It was especially stated that the survey questioned institutional habits of the trauma center rather than individual ones. Only one response by each trauma center was considered. The data were treated in a blinded manner to maintain the anonymity of responses. This survey was developed in accordance with available guidelines for self-administered surveys [10]. No patient case was mentioned. Responses were made on a single web page with one "submit" button that only allowed submissions via these unique links, thus making non-invited responses impossible. The survey was conducted in accordance with the Checklist for Reporting Results of Internet E-survey (CHERRIES [11], Supplementary File 3).

Data Collection

The survey was designed and written by PG and then reviewed, tested, and validated by JC, HQ, and TC (as trauma experts) before being sent out. The survey was constructed in four parts:

- Identification of the trauma center (region, city, and department).
- Department organization regarding REBOA: written service protocol for indications or placement of REBOA, maximum duration of complete aortic occlusion, availability of a REBOA kit, presence of a physician referent in the trauma center.
- Experience in REBOA management: number of institutional procedures in 2022, indications, diameters of sheath, and balloon catheter, durations of aortic occlusion, used zones of aortic occlusion (Zone 1 [left subclavian artery to celiac trunk] and/or Zone 3 [lowest renal artery to aortic bifurcation]), and specific modalities of use (partial aortic occlusion [pREBOA], performance of computed tomography scan or embolization with a REBOA).
- Practice improvement: wish to receive REBOA training or to participate in a national register focused on REBOA.

Statistical Analyses

Given the purely descriptive nature of this survey, no specific statistical analysis was planned. The analysis was focused on the subgroup of trauma centers that used REBOA. Continuous variables were described as medians (interquartile ranges [IQR]) and categorical variables as absolute numbers and percentages (%). A stratification of these data was proposed according to duration of REBOA availability, as well as number of placements in 2022.

Ethical Approval and Informed Consent

Ethical approval was not required. This was an anonymous numeric survey considering no patient data, but merely an institutional organization, so no individual informed consent was required.

RESULTS

A total of 41 online responses were obtained during the study period, representing 100% of the French level-1 trauma centers. Eighteen (44%) of the centers reported REBOA use in their traumatic management. Figure 1 provides details of the distribution of these trauma centers

across the country. Among the centers using REBOA, 78% (14/18) had performed between 1 and 5 REBOA placements during 2022, 11% (2/18) between 6 and 10, and 6% (1/18) 10 or more placements during the year. This number of annual procedures increased with the duration of REBOA availability in the center (Figure 2*a*,*b*).

In the subgroup of centers using REBOA, 28% (5/18) implemented a protocol for procedure and placement. According to hemorrhagic context, 100% (18/18) of the centers used REBOA on the source of pelvic bleeding, 78% (14/18) on the source of abdominal bleeding, and 67% (12/18) on the source of lower limb bleeding. An anesthesiologist-intensivist served as the operator in half of the centers (9/18), while the operator was a surgeon in 28% of centers (5/18), and an interventional radiologist in 22% of centers (4/18). The duration of REBOA availability in the center did not appear to directly influence the involvement of anesthesiologist-intensivists (Figure 2*c*).

Concerning aortic occlusion practices, 39% (7/18) of the centers used REBOA in Zone 1. The maximum durations of complete occlusion allowed in the

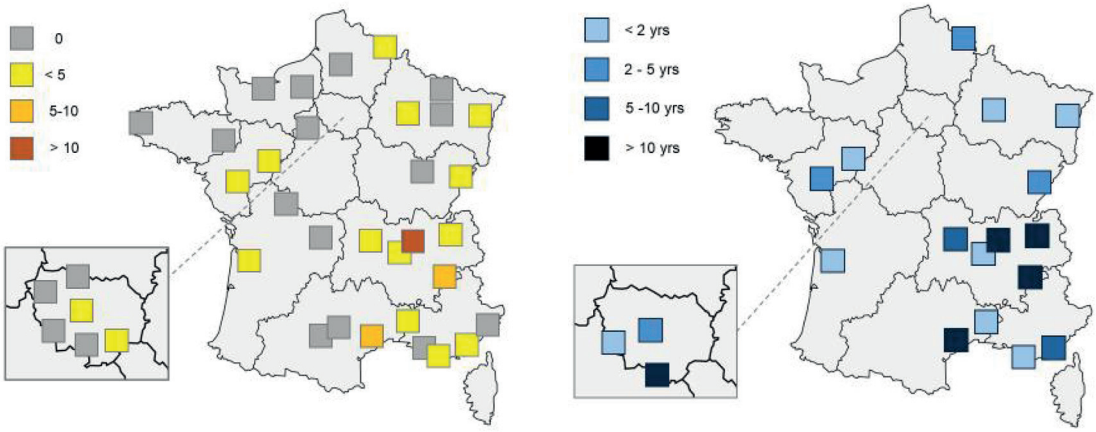

Figure 1 REBOA use in French level-1 trauma centers.

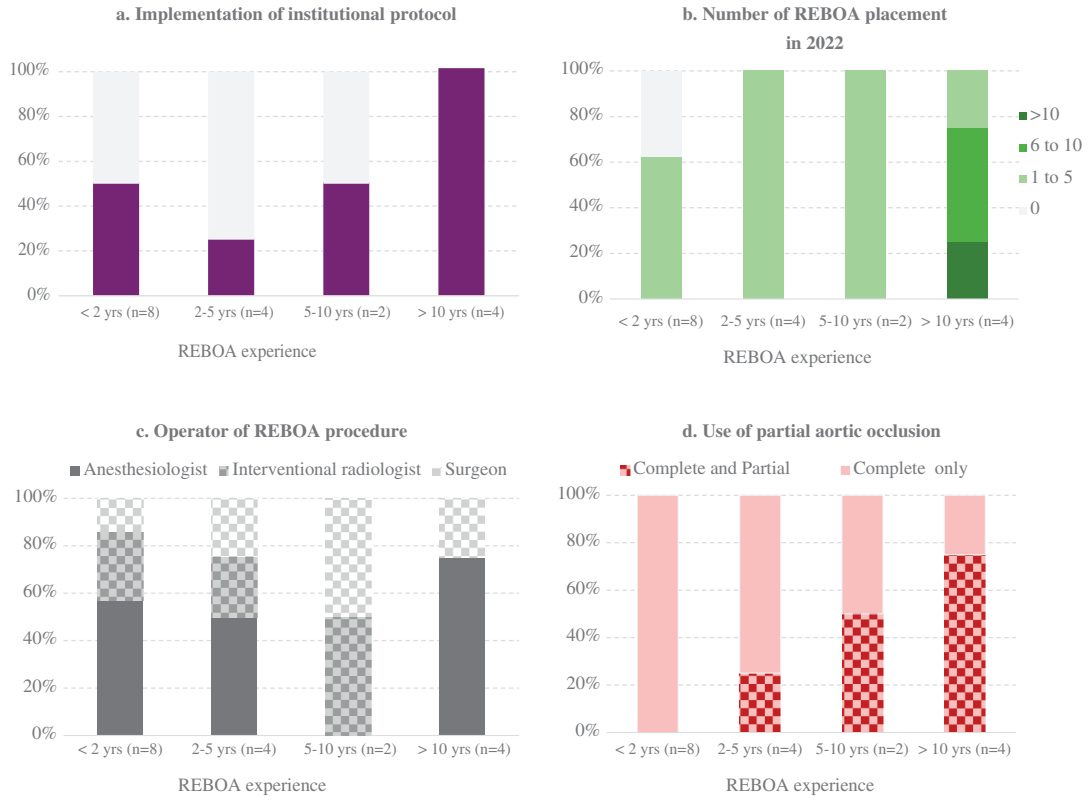

Figure 2 Clinical practices focused on REBOA in French level-1 trauma centers.

protocols were, as expected, higher for Zone 3 (Figure 3). Only 50% of centers (9/18) had a protocol for Zone 1 with a duration limit of complete aortic occlusion; there were 22% (4/18) at 30 minutes, 17% (3/18) at 45 minutes, 11% (2/18) at 60 minutes, and none at 120 minutes. This rate was 78% (14/18) for Zone 3; corresponding values were 6% (1/18), 11% (2/18), 28% (5/18), 17% (3/18), and 39% (7/18), respectively. The practice of pREBOA was used in 33% (6/18) of the centers, increasing with REBOA experience (Figure 2*d*).

Figure 4 provides details of the types of complications observed in the trauma centers with REBOA use. The main reported complication was vascular, either distal ischemia or dissection injury, with 50% (9/18) of the centers reporting this complication, albeit in a minor proportion of cases. Hemorrhagic complications were also observed (28%; 5/18) as well as septic complications (17%; 3/18).

Finally, a majority of the 41 French level-1 trauma centers declared their wish to receive theoretical information (80%; 33/41) or practical training (83%; 34/41) on the placement of REBOA. Eighty-eight per cent of centers (36/41) also declared that they were interested in participating in a national register or study.

DISCUSSION

In our national survey that specifically assessed the use of REBOA in all French level-1 trauma centers, we highlighted that less than half of these institutions had experienced at least one REBOA placement. While almost all of these centers had a specific protocol, the proportion of those using REBOA in Zone 1 was lower than 40%, and only one-third of centers used partial REBOA. In half of these centers, REBOA procedures were performed by anesthesiologist-intensivists. For the year 2022, the majority of centers using REBOA

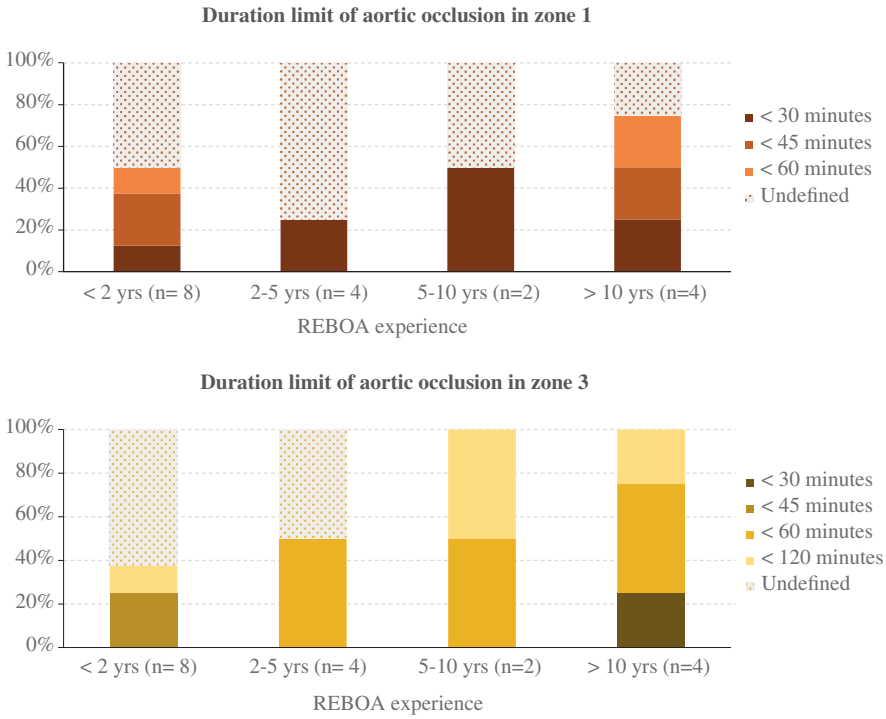

Figure 3 Protocol of aortic occlusion durations.

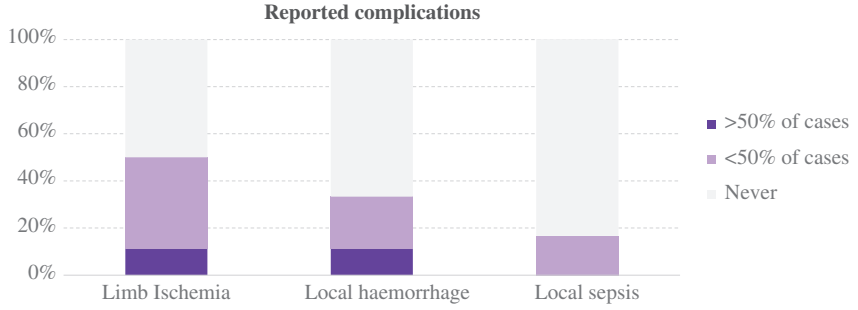

Figure 4 Specific local complications related to REBOA.

reported a number of placements lower than 5, with almost all reporting a number of placements lower than 10. Therefore, to date, REBOA remains poorly distributed and rarely used in the context of trauma in France.

Several characteristics of REBOA would seem to make this life-saving procedure an attractive tool in the French trauma system. Firstly, there is its simplicity of placement for an anesthesiologist-intensivist, who receives trauma patients in most French level-1 trauma centers [7,12]. Historically, REBOA has been proposed using a surgical approach, making this hemostatic intervention relevant mainly in countries where trauma surgeons are the first physicians upon admission [13]. These last years, the percutaneous approach has been successfully adopted by many teams, establishing it as the current standard of care [14]. The percutaneous approach appears thus to be more suitable for anesthesiologist-intensivists who are accustomed to these vascular access techniques, especially helped by ultrasonography [8,9]. Secondly, REBOA is reputed to be more relevant in cases of multiple injuries or multiple bleeding sources [15,16]. REBOA could therefore be of valuable help for the anesthesiologist-intensivist in the presence of multiple bleeding sources to limit blood loss, while activation and coordination of different physicians may be challenging [16]. In addition to temporarily stopping the bleeding, aortic occlusion in cases of massive blood loss helps maintain acceptable hemodynamic targets to preserve cerebral and coronary perfusion [17]. Optimization of these physiological parameters, which are the cornerstone of trauma resuscitation, is indeed crucial in the presence of traumatic brain injury or multiple organ failure. All these arguments therefore play in favor of REBOA use in French trauma centers and its placement by anesthesiologist-intensivist in the emergency room. However, one of our main findings is that less than 50% of French trauma centers had used REBOA up until the start of our survey. We hypothesize that the transfer of a surgical technique to another specialty takes longer to implement. Moreover, only half of the centers that have incorporated REBOA into their therapeutic arsenal have declared in our study that this procedure was performed by anesthesiologist-intensivists. A better understanding of clinical experience could probably help to propose guidelines for this practice in a trauma setting.

While the efficacy of REBOA for trauma has been widely recognized compared to resuscitative thoracotomy or open aortic occlusion, its use in the country appears to be limited [6,18,19]. This technique may indeed be intimidating for physicians due to the potential for misuse, which could lead to local complications or ischemia-reperfusion injuries. Another concern is the possible additional delays that could be generated by the introduction of REBOA in acute bleeding management. So, how should we analyze the specific constraints related to REBOA in the French trauma system? Firstly, the risk of time loss is a significant concern when considering REBOA. Delaying hemostatic control is obviously undesirable and could result in a higher mortality rate [20]. Using a Bayesian analysis, a prospective randomized series indeed suggested that lost time in the REBOA group might induce a higher mortality rate. However, there were limitations in this cohort, such as a low proportion of hemostatic interventions, questioning of selection criteria for included patients, or delays in achieving hemostatic interventions. Anyway, this specific concern is still unresolved, leading to possible doubts as to the benefit of REBOA. What is certain, in contrast, is that the REBOA procedure must be timed, and a maximum duration must be defined in the center protocol. Following this reasoning, Brenner et al. [2] demonstrated that aortic occlusion can be achieved within a few minutes in most cases when physicians are trained, whether in cardiac arrest or circulatory shock. Secondly, the morbid consequences of mesenteric or hepatic ischemia-reperfusion are well known in cases of aortic occlusion, necessitating a limit on occlusion duration to 30–40 minutes in Zone 1 and 120–180 minutes in Zone 3 [21,22]. Physicians must know that failure to respect this timing can be lethal, even if the bleeding source is controlled. However, a partial occlusion was demonstrated to allow a longer use of REBOA without major consequences [23,24]. Simple monitoring of arterial pressure level below the balloon on the sheath is easy, simple, and allows one to maintain an acceptable perfusion pressure in the mesenteric, pelvic, and lower limb areas. In our survey, only one-third of the trauma centers using REBOA were familiar with pREBOA. Intermittent aortic occlusion was also proposed as an alternative to pREBOA, but with lower tolerance [25,26]. We suppose that the increase of REBOA experience could be associated with an increase of pREBOA use in the French centers, which is associated with less adverse consequences related to ischemia-reperfusion [23,24]. It is of note that, to date, only 50% of the French teams had performed aortic occlusion in Zone 1, which may explain why pREBOA was less commonly used. Thirdly, concerns about ischemic risk for the lower limb may also act as a barrier. A significant size of sheath is indeed necessary to be able to insert the balloon with a catheter that often reaches a diameter of 7Fr. Historic sheaths had large diameters (14–12Fr), and therefore it was legitimate to fear significant ischemia and local complications [18]. However, such complications were described as low in most series, particularly when sheath diameters were lower than 10Fr [14]. To date, new devices exist with lower diameters of sheath, 7Fr or smaller. These were previously not available in France. The reduction of this diameter may be the key to diffusion of REBOA in our country, simplifying its placement and decreasing the fear of critical limb ischemia or vascular complications. Fourthly, REBOA indications are very rare,

even in a level-1 trauma center, with a few per year [27]. This low rate contributes to a low knowledge of the procedure and to the fear of its complications. The more experienced clinicians are, the less fearful they become and the more comfortable they are, leading to an increase in the number of REBOA placements. This was demonstrated by our national survey where the number of annual procedures increased with the duration of REBOA availability in the center.

Although our study provides interesting and comprehensive results at a national level, it has several limitations. Firstly, numerical surveys are subject to a declarative bias. However, we clearly stated in our methodological instructions that the responses should strictly reflect the situation and practices in the centers. Secondly, our survey was conducted before the publication of two major trials, presenting a risk of changes in practices [6,20]. Thirdly, the number of annual REBOA placements was low and varied from year to year. Therefore, our analysis, which focuses on 2022, may not fully represent the usage of REBOA in France. Fourthly, the UK-REBOA study [20] reported a potential negative impact associated with misuse of REBOA, which may slow down the development of this procedure. Data collection for the present survey was, however, achieved before the publication of this work, allowing us to affirm it had a minor impact on our analysis.

To conclude, our survey revealed that the utilization of REBOA in French trauma centers prior to 2023 was modest, with less than half of the level-1 centers employing this technique. The annual number of placements in these centers remains low, highlighting the need for written and multidisciplinary protocols in each facility. These protocols should include clinical indications for REBOA placement, material, and procedural rules, as well as the timing of aortic occlusions and the modalities of balloon deflation. Interestingly, only half of the centers declared that placements were performed by anesthesiologist-intensivists, despite their primary role in patient admission. However, a large majority of centers expressed interest in receiving practical and/or theoretical training in REBOA use. Divergent conclusions from several studies, the low number of indications, and technical complexity have so far been obstacles to the development of REBOA in our country. The emergence of a national academic program and the determination of a consensual and safe place for REBOA may facilitate its adoption in expert centers.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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SUPPLEMENTARY DIGITAL CONTENT

Supplementary File 1. The ACUTE SFAR Committee 2023–2024.

Supplementary File 2. French numeric survey for practice organization in level-1 trauma centers.

Supplementary File 3. Checklist for Reporting Results of Internet E-Surveys (CHERRIES)*

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