

# Proactive Use of Whole-Body Computed Tomography and Resuscitative Endovascular Balloon Occlusion of the Aorta in Hemodynamically Unstable Trauma Patients

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It is well known that whole body computed tomography (WBCT) scans in hemodynamically unstable trauma patients (HUPs) should not be performed due to time concerns. Recently, with the shortening of CT scan time accomplished by quick preparation and scanning, WBCT in the patient population utilizing resuscitative endovascular balloon occlusion of the aorta (REBOA) in trauma cases could lead to better subsequent management, especially for patients with unknown bleeding points without known mechanism of injury, possible traumatic brain injury, and geriatric trauma with coagulopathy. During a CT scan with contrast, the REBOA balloon is not necessarily deflated further. The training of the CT scan team could shorten the CT room stay time to under 5 min. The images should be read quickly following focused assessment of the scans for trauma by trauma radiologists. REBOA–WBCT scans in HUPs with appropriate protocols and image readings might be the tool for choosing a better management in order to restrain hemorrhage.

**Keywords:** *Whole Body Computed Tomography; REBOA; Resuscitative Endovascular Balloon Occlusion of the Aorta; Hemodynamically Unstable Trauma Patients*

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## INTRODUCTION

According to the American Association for the Surgery of Trauma, traumatic injury is responsible for more than 5 million deaths annually, and prompt in-hospital trauma management is important for the survival of major trauma patients [1]. An evaluation of bleeding sites, responsible

vessels, and the amount of hemorrhage is critical for rapid circulatory restoration in a hemodynamically unstable trauma patient. Whole-body computed tomography (WBCT) is the imaging modality of choice; however, its utilization for hemodynamically unstable trauma patients is controversial [2] because it takes time, where the time spent in the CT room may exacerbate the patient's condition beyond a "point of no return".

Resuscitative endovascular balloon occlusion of the aorta (REBOA) was developed to maintain proximal blood pressure and regulate the amount of arterial bleeding [3]. It may also give an opportunity for a CT scan enabling better subsequent management, as well as determining the presence or absence of traumatic brain injury [4,5]. Meanwhile, the arguments have continued for adequate balloon inflation, and as the amount of

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balloon volume is increased, the narrower the aortic lumen becomes, and the higher the possibility of complications such as lower limb ischemia [6]. For that reason, the time of REBOA utilization should be minimal.

Previous studies have mainly focused on efforts to shorten the procedure time performed in the CT room, and few studies have focused on the preparation necessary to decrease the whole process, which starts from the patient's arrival in the emergency department (ED). We call this the 'CT room stay time' (CTrST), and previous studies show that the mean time is about 16.8 min [7]. Clarke et al. reported that the probability of death among 243 hypotensive patients, bleeding from abdominal injuries and needing emergency laparotomies, increased by approximately 1% for each 3 min spent in the ED [8]. Thus, the shorter the CTrST, the higher the likelihood of patient survival. Shortening the CTrST may be good for lowering the rate of REBOA complications as well as improving the patient's prognosis.

In this article, the authors introduce the indication and adequate utilization of REBOA.

### **Ethical Approval and Informed Consent**

Ethical approval was not required. Written informed consent was not required.

### **INDICATION OF REBOA–WBCT FOR TRAUMA PATIENTS**

The golden hour theory of trauma management was proposed by Cowley [9–11], and the author states that the mortality rate triples for every 30-min increase from the time of injury to definitive care [12]. Those articles were published in the pre-endovascular era, and the equipment for diagnosis and management have now progressed beyond comparison. In addition to widely used chest and abdominal X-rays, focused assessment with sonography for trauma (FAST), which is easily performed at the bedside, is one of the most useful tools developed for evaluating hematomas that are unable to be inspected visually. However, this technique cannot "see" several important indications, such as the severity of bleeding, precise total amount of hemorrhage or number of bleeding sites. For those reasons, WBCT is the modality of choice, and the rationale for its use is as follows.

### **Unknown Bleeding Point Without Known Mechanism of Injury**

When individuals with non-compressive blunt polytrauma arrive at the ED, chest and pelvis plain X-rays as well as FAST are performed to look for possible sources of bleeding. These modalities can evaluate intrapleural or intraperitoneal abnormalities; however, extra-pelvic retroperitoneal hemorrhage due to kidney, paravertebral,

and lumbar artery injuries is often difficult to determine. Despite this, not all retroperitoneal bleeding is lethal, and requires invasive strategies such as surgery or interventional radiology (IR), particularly in elderly patients with coagulopathy. WBCT reveals the presence of hemorrhage, which could not be achieved without it and helps us to determine the best course of management.

### **Possible Traumatic Brain Injury**

Patients with mild traumatic brain injury (TBI) may not have altered mental status upon arrival at the ED.

Especially within the context of coagulopathy, intracranial bleeding may proceed rapidly, which could lead to a robust deterioration of the patient's status, and its presence could change the order of subsequent management in patients who have other sources of bleeding, such as intraperitoneal hemorrhage. WBCT includes a plain head CT, which is sensitive and specific for hemorrhage within the skull. REBOA utilization could elevate intracranial pressure by obstructing the blood flow to the lower body; however, the use of partial occlusion instead of complete occlusion may avoid unnecessary hypertension.

### **Geriatric Trauma with Coagulopathy**

Rapid aging of the population has been occurring worldwide [13]. Aging increases the anatomical vulnerability of having a traumatic hematoma, and combined with cognitive function decline, this makes it difficult to precisely evaluate its severity. Loose tissue in older people leads to the easy expansion of a hematoma, and anti-thrombotic agents may aggravate the severity of bleeding. These components result in unexpected bleeding occurring in unexpected sites within an unusually short span of time. In addition to this, older populations frequently have decreased cognitive function, and their altered mental status is sometimes difficult to evaluate whether their status is normal without information on their baseline vital signs and history of medications, such as anti-hypertensives. Therefore, the utilization of REBOA–WBCT could give us an objective evaluation of patient status and be justified in elderly patients with a suspicion of trauma with decreased cognitive functions as well as multiple anamnesis.

### **THE STATE OF REBOA AT CT SCANNING**

There are debates on how much balloon inflation is appropriate for sufficient contrast enhancement of CT imaging. Matsumura et al. provide an example of its utilization (Supplementary Movie 1) [14]. They state that contrast enhancement could be achieved with partial occlusion although the contrast flow could be delayed compared to the state without balloon inflation. Even in the situation of a vulnerable patient whose

blood pressure is sustained only with complete occlusion, the contrast flow is still observed peripheral to the balloon; however, the potential complications of underestimation of extravasation must be considered in the interpretation of images.

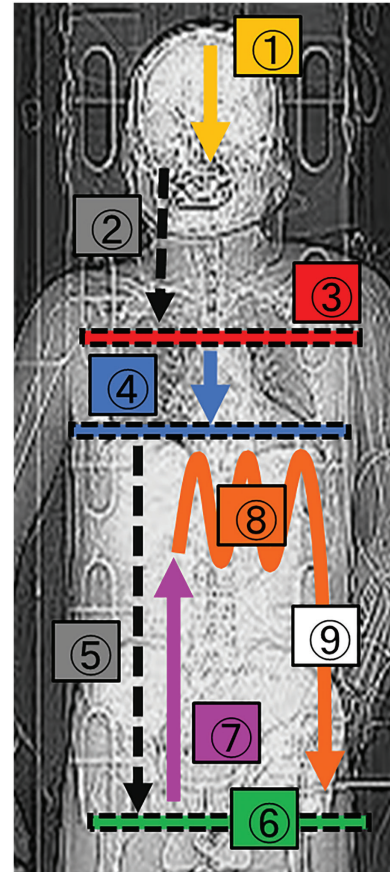
### HOW LONG IS TOO LONG? SHORTENING THE CT ROOM STAY TIME

The utilization of REBOA is, of course, not the fundamental management. REBOA-WBCT has an impact on subsequent management, especially in the situations mentioned above; however, it is itself not without complications. Therefore, the time for CT should be as short as possible to provide a better outcome.

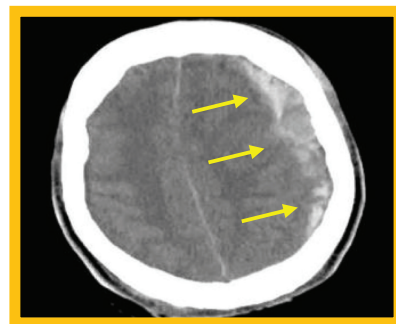
No hospital without a trained trauma team accepts hemodynamically unstable trauma patients, because performing unfamiliar tasks is more time-consuming than completing routine ones. For this reason, specialist trauma surgeons are needed. IR for trauma patients has been widely used for rapid and precise management. In the same way, WBCT teams should also be trained. Matsumoto et al. have advocated prompt and rapid endovascular strategies in trauma occasions (PRESTO) [15].

When the patient arrives in the ED, the WBCT team begins to gather the information necessary for prompt CT scanning. They check the height of the stretcher, determine whether the patient can raise their arms and whether the intravenous line needs to be longer. Untangling the intravenous lines, electrocardiogram equipment and blood pressure cuff is an important task. In addition, removing any metallic objects that might appear as artifacts on the CT image is also essential. All the information is relayed to the radiology technicians in the CT room. The radiology technicians turn on the CT machine so that it is ready to scan, and adjust the height of the bed to match that of the patient's stretcher. Nurses prepare iodine contrast for use at any time.

Once the patient has been placed on the CT scan bed and the medical personnel have left the room, the contrast media injection is started. Scout image acquisition is skipped, and head CT scanning commences before the contrast media reaches the cerebral arteries. When the region of interest in the aorta is filled with contrast, which usually takes about 40 s, the arterial phase is started, followed by the venous phase. Once the scan is completed and the patient has left the room, the image evaluation is started immediately by a radiologist, which could be continued even in the operating room, and annotations are discussed. Using the PRESTO concept and a trained team, the CTrST was shortened to <5 min (Supplementary Movie 2). In the practice using a mannequin, the time was shortened further to <3 min (Supplementary Movie 3). As discussion of the CT annotations would help subsequent management, the short amount of time that this procedure takes was considered to outweigh the risk of further deterioration in most cases.



**Figure 1** The reading order of the CT images during the focused assessment with computed tomography (FACT) for trauma protocol. Figures 2 to 5 explain details and examples.

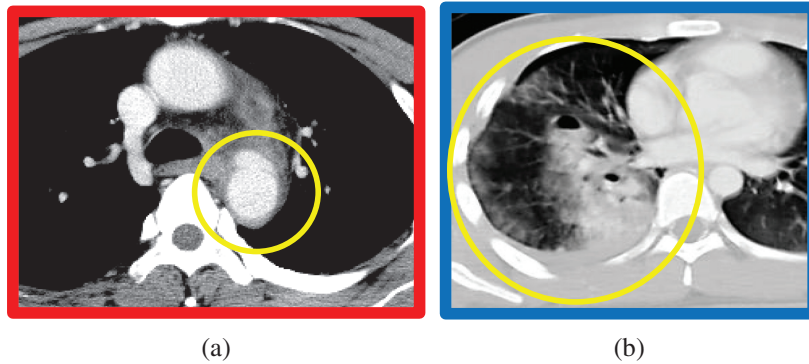


**Figure 2** The image is assessed for the presence of potentially lethal intracranial lesions, such as massive hemorrhage in the mediastinal window. The neck is evaluated in the superior view. The image shows an intracranial hemorrhage.

### OPTIMIZING UTILIZATION OF CT IMAGES

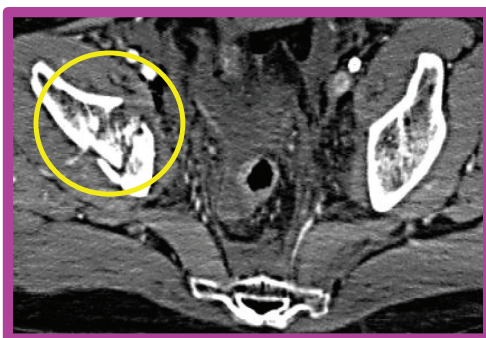
CT images must be read precisely to quickly acquire the information mentioned above. Ichinose et al.





**Figure 3** The thoracic area is evaluated for aortic injury and mediastinal hematoma. The lung window was changed at the level of the diaphragm, and a large lung contusion or pneumothorax, as well as a massive hemothorax, was viewed superiorly. Coronal views of the contrast-enhanced CT showing aortic dissection (a) and lung contusion (b).

recommended rapid reading of the CT pan-scan for trauma evaluation (focused assessment with computed tomography for trauma, FACT) [16]. FACT is a systematic method for appropriately annotating images, which is necessary for subsequent management (Figures 1–5) as the book “Current Practice and New Developments in Trauma” indicates [17]. Things to bear in mind are that extravasation could be underestimated, and that the circulatory status could be evaluated with the amount and distribution of hematoma. A trauma radiologist is the best person for that job, but they are not available at all sites at all times. If they are not on site, then an exclusive image evaluator should be chosen who concentrates on the image interpretation so that the remarks of the CT scan can be passed smoothly and quickly to the trauma team. Shortening the whole process, including the CTrST, should be considered for successful management.



**Figure 4** The upper abdomen was skipped, and the mediastinal window was acquired to evaluate hematoma in the rectouterine or rectovesical pouch. Then, the CT window was changed to the bone window, to check for massive fractures in the pelvis or vertebrae. The image shows right pelvic bone fracture in the bone window.

## LIMITATIONS

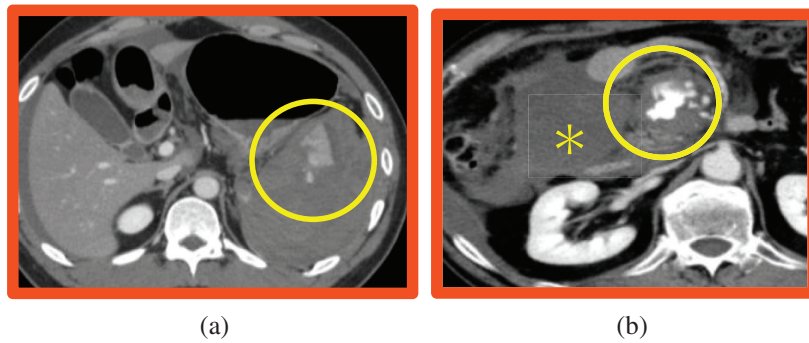
There are several limitations to performing WBCT in hemodynamically unstable patients (HUPs). First of all, CT utilization is presupposed in those patients, and there is a possibility of its overuse. The scout image is skipped, which leads to additional radiation exposure. Also, in cases of total REBOA occlusion or necessitating REBOA volume increase in the CT room due to blood pressure deterioration, the occluding time would be long, and the ischemic and reperfusion injury would be severe. Hybrid emergency room could be a savior for those patients since surgery or IR could be performed seamlessly without patient transportation from the ED; however, there are often a limited number of facilities with the required machine. Regardless of the limitations, REBOA utilization could give a chance for WBCT in HUPs who satisfied appropriate indications, and there are possibilities of effecting better management.

## CONCLUSIONS

Although utilization of WBCT with REBOA for hemodynamically unstable trauma patients has been considered to be contraindicated, a CT scan might provide better subsequent management, especially for patients with unidentified bleeding sources, an unknown mechanism of injury, coexisting TBI, or trauma in elderly with adequate knowledge of the protocols and interpretation. Shortening CTrST with the training of the CT scan team could lead to better management of patients so as to shorten the time length from trauma occurrence to completion of management.

## Ethics Statement

- (1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the



**Figure 5** Massive injuries and contrast enhancement of the intra- or extra-abdominal organs are checked for in the upper abdomen view. Coronal views of contrast-enhanced CT showing the splenic hemorrhage (a) and intraperitoneal extravasation (b) with the hemorrhage indicated by an asterisk (\*).

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.

### Funding

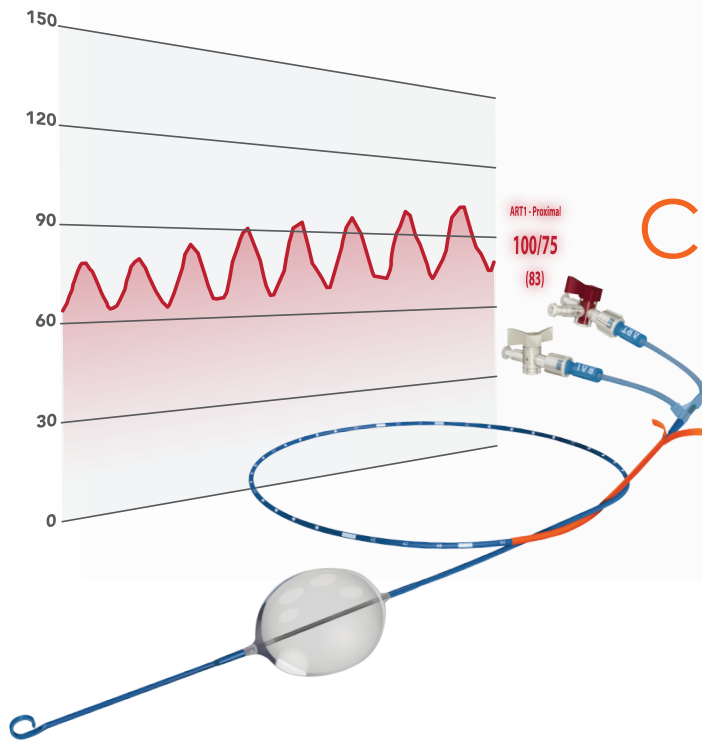
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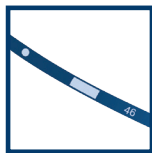
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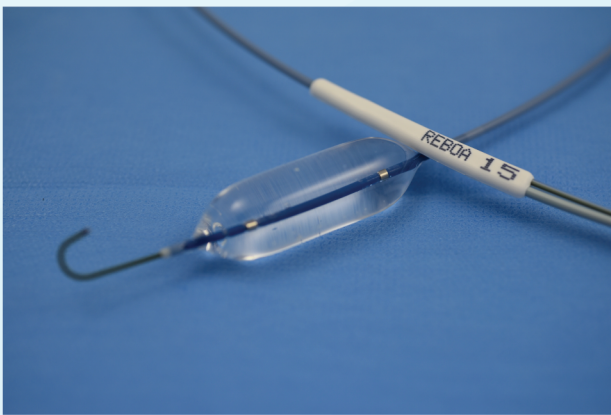
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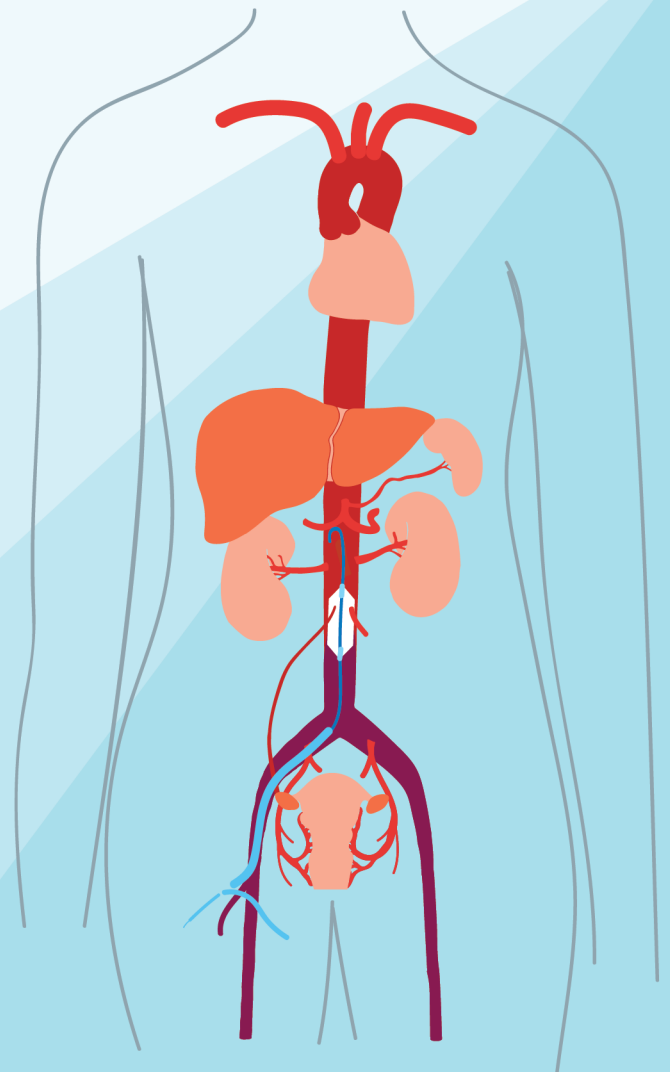
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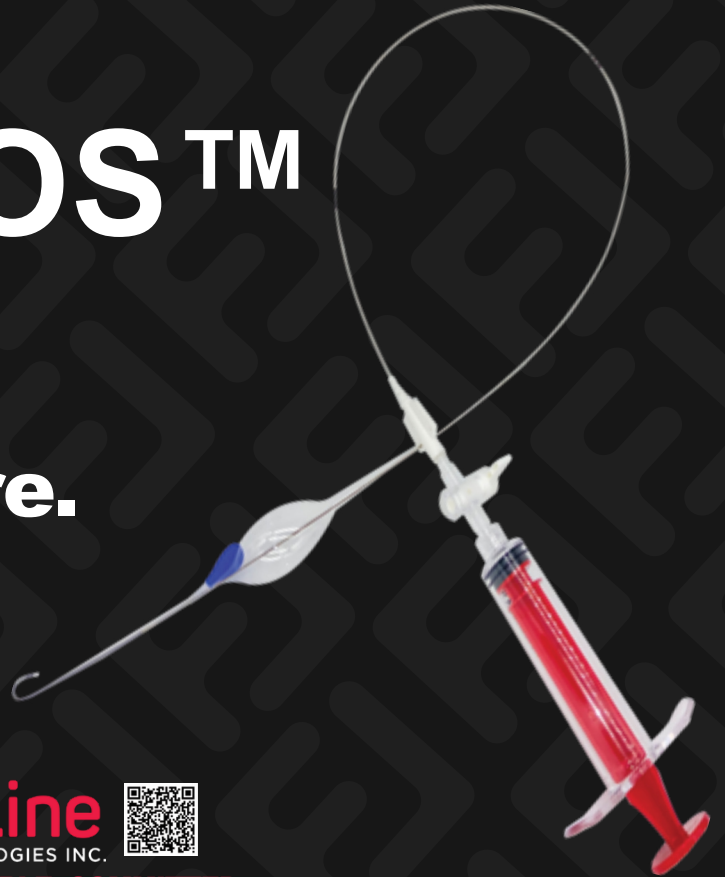


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