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Use of REBOA in the universe of magical realism: a real-world review

Uso de REBOA en el universo del realismo mágico: revisión de vida real

Ramiro Manzano-Nuñez^a , Julián Chica-Yanten^a, Maria P. Naranjo^b, Isabella Caicedo-Holguin^a, Juliana M. Ordoñez^f, David McGreevy^d, Juan C. Puyana^c, Tal M. Hörer^d, Ernest E. Moore^e, Alberto F. García^f

^aClinical Research Center, Fundacion Valle del Lili. Cali, Colombia.

^bGeneral Surgery, Fundacion Universitaria Sanitas. Bogotá, Colombia.

^cDepartment of Surgery, University of Pittsburgh. Pittsburgh, USA.

^dDepartment of Cardiothoracic & Vascular Surgery, School of Medicine & Health, Örebro University. Örebro, Sweden.

^eDepartment of Surgery, School of Medicine, University of Colorado Denver. Aurora, USA.

^fDepartment of Surgery, Fundación Valle del Lili. Cali, Colombia.

Correspondence: Av. Simón Bolívar, Cra 98 No. 18-49, Fundación Valle del Lili. Cali, Colombia.

Email: ramiro.manzano@correounivalle.edu.co

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Abstract

While reading the novella “Chronicle of a Death Foretold” by the Colombian Nobel Laureate Gabriel García-Marquez, we were surprised to realize that the injuries sustained by the main character could have been successfully treated had he received modern trauma care in which REBOA may have been considered. This is a discussion of Mr. Nasar’s murder to explore whether he could have been saved by deploying REBOA as a surgical adjunct to bleeding control and resuscitation. In reading García-Marquez’s novel we noted the events that unfolded at the time of Santiago Nasar’s murder. To contextualize the claim that Mr. Nasar could have survived, had his injuries been treated with REBOA, we explored and illustrated what could have done differently and why. On the day of his death, Mr. Nasar sustained multiple penetrating stab wounds. Although he received multiple stab wounds to his torso, the book describes seven potentially fatal injuries, resulting in hollow viscus, solid viscus, and major vascular injuries. We provided a practical description of the clinical and surgical management algorithm we would have followed in Mr. Nasar’s case. This algorithm included the REBOA deployment for hemorrhage control and resuscitation. The use of REBOA as part of the surgical procedures performed could have saved Mr. Nasar’s life. Based on our current knowledge about REBOA in trauma surgery, we claim that its use, coupled with appropriate surgical care for hemorrhage control, could have saved Santiago Nasar’s life, and thus prevent a death foretold.

Keywords

Resuscitative balloon occlusion of the aorta; REBOA; Endovascular resuscitation; Trauma management; Non-compressible torso hemorrhage.

Resumen

Leyendo la novela "Crónica de una muerte anunciada" del Nobel de Literatura Gabriel García Márquez, nos sorprendió reconocer que las heridas provocadas al personaje principal se habrían podido tratar exitosamente en un centro de trauma moderno donde hubieran optado por REBOA. Hacemos referencia al asesinato del señor Nasar para explorar la posibilidad de que se hubiera podido salvar de haberse utilizado REBOA como adyuvante de la cirugía para reanimación y control de la hemorragia. En la lectura de la novela de García Márquez tomamos nota de los sucesos que tuvieron lugar en el momento del asesinato de Santiago Nasar. Para contextualizar la afirmación de que Nasar habría podido sobrevivir si le hubieran manejado sus heridas con REBOA, exploramos e ilustramos lo que habría podido hacerse de otra manera y porqué. El día en que murió, el señor Nasar sufrió múltiples heridas por arma blanca y si bien muchas de ellas fueron en el torso, el libro describe siete heridas mortales que comprometieron los órganos sólidos, además de lesiones vasculares mayores. Presentamos una descripción práctica del algoritmo para el manejo clínico y quirúrgico que habríamos seguido en el caso del señor Nasar. Este algoritmo incluye el uso de REBOA para el control de la hemorragia y la reanimación, el cual, como parte de los procedimientos quirúrgicos realizados, habría podido salvarle la vida a la víctima. Basados en nuestro conocimiento actual acerca del uso de REBOA en la cirugía de trauma, planteamos que, junto con la atención quirúrgica apropiada para controlar la hemorragia, este procedimiento habría podido salvarle la vida a Santiago Nasar y, por tanto, evitar una muerte anunciada.

Palabras clave

Balón de reanimación endovascular de oclusión aórtica; Oclusión aórtica con balón; REBOA; Reanimación endovascular; Manejo del trauma.

BACKGROUND

Chronicle of a death foretold (Crónica de una Muerte Aunciada) is a novella by the Colombian Nobel laureate Gabriel García-Marquez, first published in 1981. (1) The book, written in a magical realism style, portrays the bloody murder of Santiago Nasar at the hands of the Vicario Brothers who viciously stabbed him in his torso in broad daylight in a crowded public square. From the detailed depiction of the wounds inflicted by the Vicario brothers, albeit without granular knowledge of injuries, it is rational to speculate that Mr. Nasar died from potentially survivable injuries.

Unlike the real world, where injuries and violence are preventable, Mr. Nasar's death was not. A fact that was made clear in the first sentence of the book: "On the day they were going to kill him, Santiago Nasar got up at five-thirty in the morning to wait for the boat the bishop was coming on." It is, therefore, possible that no one could have been able to stop the injuries and violence depicted in the book; however, much could be done to reduce the deleterious effects

of penetrating wounds and hemorrhagic shock, improve patient outcomes and ultimately save Mr. Nasar life. In this regard, strategies aimed at improving resuscitation, preventing the collapse of the systemic circulation, and preventing death from hemorrhage should have been delivered to increase the odds of Mr. Nasar's survival.

There has been a growing interest over the past years in technological advances in hemorrhage control, which has led to a paradigm shift towards the practice of Endovascular Resuscitation and Trauma Management (EVTM) (2). For example, Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), which involves deploying an endovascular balloon occlusion catheter into the aorta, has gradually become part of the therapeutic armamentarium for injured patients with hemorrhagic shock (3-6). Its use has expanded worldwide (6-8), and the data generated so far has provided hope that this intervention could lead to lasting changes in the outcomes of non-compressible torso hemorrhage (NCTH)

patients by reducing the risk of early death associated with uncontrolled hemorrhage (9,10). Moreover, safely REBOA deployment has been reported in non-trauma scenarios (i.e., abnormal placentation, post-partum hemorrhage, upper gastrointestinal bleeding) where its use contributed to providing hemodynamic support or the salvage of impending hemorrhagic shock. (11,12)

While reading Garcia-Marquez's book, we were surprised to realize that the injuries sustained by Mr. Nasar were potentially survivable, had he received modern trauma care in which REBOA may have been considered. This article discusses the case of Mr. Nasar's murder to explore whether he could have been saved by deploying REBOA as a surgical adjunct to bleeding control and resuscitation. We hypothesize that REBOA deployment may have resulted in a favorable outcome.

The case description is based on data from the novella Crónica de Una Muerte Anunciada <Chronicle of a Death Foretold>, written by Nobel Laureate Gabriel García-Marquez in 1981. It tells the story of the

murder of Santiago Nasar by the Vicario brothers.

Patient data and data extraction: Two trained physicians independently (one MD research fellow and one resident of surgery) read García-Marquez's novella between March and May 2020. They kept contemporaneous notes of the events that occurred at the time of Santiago Nasar's murder and made a judgment about the injuries and their severity. An experienced trauma surgeon resolved any disagreements over injury scores and data extracted from the book.

How would we treat the patient? To contextualize the claim that Mr. Nasar could have survived, had his injuries been treated with REBOA, we analyzed and illustrated what we could have done and why. Therefore, providing a practical description of the clinical and surgical management more appropriate to Mr. Nasar's case.

The case described in this report was part of the universe of magical realism created by Gabriel Garcia-Marquez. The proposed surgical care is part of our trauma-care literacy and based on what is currently known about REBOA. We would have followed the protocol proposed, had Mr. Nassar been treated in a real-world environment during routine clinical care.

Santiago Nasar was a 21-year-old male who was intentionally stabbed by the two Vicario brothers (Pedro and Pablo) in a small town located somewhere on the Caribbean coast of Colombia. On the day of his death, Mr. Nasar was inflicted multiple penetrating stab wounds.

The book described that the Vicario brothers repeatedly stabbed Mr. Nasar. Although he received multiple stab wounds to his torso, the book describes seven potentially fatal injuries: (1) "The knife went through the palm of his right hand and then sank into his side up to the hilt" (He received two more stab injuries almost in the same

TABLE 1. Description of the interpretation of Santiago Nasar's Injuries.

Injuries	Which organs were probably affected?	AAST Scoring	AIS	Did the injury cause non-compressible bleeding?
(1) Right thoracoabdominal stab injury	Liver: Liver laceration. Diaphragm: Right diaphragmatic laceration	Grade III liver injury Grade II-III diaphragm injury	3	Yes
(2) Posterior abdominal stab injury with blood spurting from the wound	Injury to retroperitoneal structures, including major blood vessels, and solid organs	Grade IV abdominal vascular injury	3	Yes
(3) Stab injury to the armpit	Thoracic injury: Lung laceration, thoracic vascular injury	Grade I-II thoracic vascular injury/ Grade IV lung injury	3	Yes
(4) Anterior abdominal stab wounds with evisceration	Abdominal Injury: Small bowel and/or colon laceration	Grade II, III small bowel/colon injuries	3	No
(5) Stab wound to the thigh	None	NA	1	NA

SOURCE: Authors.

place); (2) "Pablo Vicario, who was on his left, then gave him the only stab in the back and a spurt of blood under high pressure soaked his shirt"; (3) "Trying to finish it once and for all, Pedro Vicario sought his heart, but he looked for it almost in the armpit, where pigs have it"; (4) "Desperate, Pablo Vicario gave him a horizontal slash on the stomach, and all his intestines exploded out"; (5) "Pedro Vicario was about to do the same, but his wrist twisted with horror and he gave him a wild cut on the thigh".

The consensus of the review team about injuries sustained by Mr. Nasar is highlighted in Table 1, including injury descriptions, corresponding American

Association for the Surgery of Trauma (AAST) injury scores, and Abbreviated Injury Scale (AIS) scores.

Mr. Nasar was found to have multiple injuries to his organs, resulting in an overall Injury Severity Score (ISS) of 19. These injuries correspond to a pattern of penetrating injuries categorized as "severe trauma" (ISS≥16). He had hollow viscus, solid viscus, and major vascular injuries.

Data about Mr. Nasar's hemodynamic status was not provided. However, three of the five injuries could result in non-compressible torso hemorrhage.

After sustaining these injuries, Mr. Nasar was able to walk more than a hundred yards, before falling down dead.

HOW WOULD WE TREAT THE PATIENT?

Before describing how we would treat Mr. Nasar's injuries, we want to acknowledge some prehospital resuscitation strategies that could have improved his chances of survival.

Because the mode of transportation of severely injured patients is associated with outcomes, Mr. Nasar should have been transported from the scene of injury to definitive surgical care at a health care facility as quickly and safely as possible (13), and preferably to a certified trauma center as this has been proven to reduce the overall risk of death. (14) Intubation should be deferred at this point and, if feasible, transfusion of plasma should be preferred over crystalloid resuscitation if prolonged transport times are anticipated. (15) However, systolic blood pressure should not be increased above 80mmHg during transportation.

Although data from case series suggest that pre-hospital REBOA is feasible (16), even in austere environments (17), there must be appropriate expertise and certain injury patterns to warrant this intervention. Therefore, due to an uncertain tradeoff between the benefits and harms of pre-hospital REBOA use, we advise that REBOA should be reserved for in-hospital use.

Initial evaluation at the trauma bay

On arrival at the emergency department (ED), Mr. Nasar would have been assessed following ATLS and institutional protocols. In our institution, patients with penetrating trauma to the torso and profound hypotension (SBP<70 mm Hg), unresponsive hypotension, or undergoing cardiopulmonary resuscitation are transferred immediately to the operating room for resuscitation and hemorrhage control.

We prefer not to insert REBOA in the emergency department (ED) because it may further delay patient transfer to the operating room and timely bleeding

control. However, if trauma centers guarantee that patients will receive definitive surgical care and hemostasis on time, then the early deployment of REBOA in the ED should not be discouraged. It may underpin the patient's initial ability to survive the hemorrhagic shock.

The initial assessment could have included Focused Assessment with Sonography for Trauma (FAST) to detect free fluid and a chest x-ray to rule-out either pneumothorax or hemothorax. A chest tube could have been inserted if required.

Because of the topography of the injuries and the likelihood of NCTH, In all likelihood, Mr. Nasar could have undergone a surgical procedure for hemorrhage control. Had Mr. Nasar presented the injuries described in Table 1, we would have performed an exploratory laparotomy with simultaneous REBOA deployment.

Furthermore, if during the initial assessment, Mr. Nasar presented with clinical or radiologic features prompting intrathoracic surgical intervention, two teams would have performed a median sternotomy with REBOA in place as the surgical approach of choice. (18,19) The choice of a median sternotomy is based on the knowledge that this approach provides optimal access to the heart, lungs, and great vessels (18). The choice of REBOA over resuscitative thoracotomy rests on the knowledge that REBOA may improve the survival of exsanguinating patients with impending hemodynamic collapse, compared to RT. (9,20)

We believe that the use of REBOA in the cases described above is supported by previous studies showing that this intervention may be safely used in penetrating thoracic, abdominal, and pelvic trauma (19,21). Moreover, lower-risk adjusted odds of mortality have been reported when REBOA is deployed for penetrating trauma. (22)

REBOA INSERTION AND DEPLOYMENT

For REBOA use, Mr. Nasar could have been transferred to the operating room.

However, insertion in the ED could have been possible as well. Once in the OR, two surgical teams could have performed REBOA insertion and deployment (Team 1), and surgical interventions for hemorrhage control (Team 2). (18,19)

The descriptions of how REBOA can be used effectively in patients with penetrating trauma, including those with intrathoracic injuries, have been outlined in previous publications. (18,19,22,23) A description of the protocol that we would have used for REBOA deployment is described below.

Femoral artery cannulation is achieved either by open surgical cutdown or percutaneously via ultrasound guidance. An introducer sheath is inserted, through which REBOA is deployed in zone 1 of the aorta. Zone 1 extends from the origin of the left subclavian artery to the celiac artery. External landmarks guide the REBOA insertion. Deployment is confirmed clinically, either by a rise in systolic blood pressure or by direct visualization of the REBOA inflated in the aorta.

In cases of intrathoracic injuries, the balloon is inflated in zone 1 of the aorta. Although this procedure is concurrent with surgical interventions for bleeding control (two-team approach), inflation of the REBOA generally occurs before hemorrhage control. Using REBOA for full aortic occlusion when there are injuries above the point of occlusion theoretically increases the bleeding rate from the injury. However, we deploy REBOA in these patients as a resuscitative tool which restores blood flow to essential organs – improving cardiac and cerebral perfusion and compensating for the loss of anesthetic-induced or PPV-induced reduction of mean systemic pressure and preload (24).

In cases of abdominopelvic injuries, the balloon is also inflated in zone 1 of the aorta. However, it is repositioned in zone 3 of the aorta once the abdominal bleeding has been surgically controlled, because there is a 30 min warm ischemic tolerance of the viscera. Furthermore, abrupt deflation in zone 1 may result in immediate restoration of blood flow below the occlusion level

with subsequent washout of metabolic byproducts and acidosis, thus increasing the chance of reperfusion injury (22). In addition, inflation at zone 3 temporizes pelvic hemorrhage until stabilization, pelvic packing and/or embolization can occur.

The catheter and the sheath are removed after controlling the sources of hemorrhage and the coagulation status is normalized. Then, the distal arterial flow is assessed with a Doppler probe, and vigilant monitoring of potential extremity ischemia continues for 24 hours.

SURGICAL MANEUVERS THAT WE WOULD HAVE PERFORMED WITH REBOA IN PLACE

The method for definitive hemorrhage control of Mr. Nasar's injuries could have been chosen according to the anatomy of the injury. The decision to perform damage control surgery would have been based on early or intraoperative evidence of physiological exhaustion, or the presence of multiple bleeding sources with associated coagulopathy (25,26). All surgical interventions could have been performed with REBOA for hemorrhage control and resuscitation.

Any existing lung injuries could have been treated using lung-sparing techniques (27). Intrathoracic vascular injuries could have been repaired depending on the vessel injured and the grade of the vascular injury (25).

The liver could have been packed with laparotomy pads, if possible (28). The left-sided abdominal viscera medially rotated to allow exposure of the entire abdominal aorta (29), and the suspected retroperitoneal vascular injury repaired with REBOA in zone 1 to achieve proximal bleeding control.

Hollow viscus injuries could have been repaired either by performing a primary repair or a delayed anastomosis (30). For delayed anastomosis, the affected intestine segment could have been resected, and the

proximal and distal end left temporarily in discontinuity. The abdomen could have been packed with laparotomy pads and closed using a vacuum-assisted (VAC) dressing.

After surgery, Mr. Nasar could have been transferred to the surgical intensive care unit for hemodynamic monitoring and resuscitation. One or two days later, once the 'triad of death' (i.e., acidosis, hypothermia, and coagulopathy) was under control, he could have been taken back to the OR for definitive repair of injuries, packing removal and closure of the surgical incisions.

DISCUSSION

This paper dissects a fictional challenging trauma case to describe how we could have treated Mr. Nasar using REBOA as a surgical adjunct for hemorrhage control and resuscitation. Although Mr. Nasar's surgical outcomes are difficult to ascertain, if our protocol had been followed in a real-world trauma center, we believe that the application of REBOA as part of the surgical procedures performed could have saved his life. However, this is just one case from the universe of magical realism created by Gabriel García-Marquez, and caution should be exercised, considering the approach herein suggested might not be as promising as it could have been if it had happened in a magical realism-controlled setting.

The most important limitation of this report is the fact that, unlike the real world, where several factors influence exposures and outcomes, we deliberately assigned the exposure and a favorable outcome to Mr. Nasar with the stroke of a pen. Nevertheless, this is consistent with magical realism, in which fantastical events are portrayed in an otherwise realistic tone, that García-Marquez imprinted on his books. The end result is that we were able to depict a realistic view of modern trauma care, while adding fictional elements to the case discussed.

We argue that the use of REBOA as a surgical adjunct for hemorrhage control and resuscitation could result in a favorable survival outcome for Mr. Nasar. Nevertheless, the precise role of this endovascular intervention in the critically injured patient remains unclear. While large-database studies, where REBOA was compared to resuscitative thoracotomy, indicate a survival benefit for REBOA (9,31), similar studies comparing REBOA versus usual care have not been conclusive (32-34). However, these studies probably included heterogeneous populations of trauma patients, which in turn reduces the likelihood of determining the true intervention effect, even after using robust statistical techniques. Moreover, the probable lack of uniformity of surgical and REBOA approaches between the reporting centers may have affected the outcomes observed. In contrast, a recent study found that REBOA may add a survival benefit if used in specific subsets of injured patients, specifically those who do not require CPR before aortic occlusion (20). Furthermore, it has been shown that the survival rate in patients with traumatic cardiac arrest resuscitated with REBOA, early upon hospital admission, is significantly higher than predicted by trauma severity scores (35).

In this report, we suggest using REBOA in a patient whose presumed injuries would likely have resulted in NCTH, thus requiring immediate hemorrhage control. The mainstay of NCTH treatment is to arrest the hemorrhage as quickly as possible, and in most cases following a damage control approach (36), tailored to the clinical scenario and resources available (3). The main goal of deploying REBOA in NCTH patients is threefold: first to prevent the hemodynamic collapse further worsened by anesthetic-induced or PPV-induced reduction of the mean systemic pressure and preload; second, to achieve proactive aortic control and proximal control of hemorrhage; thirdly, to restore proximal blood flow to essential organs; i.e., improving cerebral and cardiac

perfusion. (37) Overall, the physiological repercussions of REBOA give the surgeon additional crucial time to access and control the source of hemorrhage on time. Indeed, previous studies showed that REBOA might underpin the patient's ability to survive the first hit caused by significant blood loss, resulting in fewer deaths from hemorrhagic shock. (5,20)

Although the use of REBOA in patients with penetrating trauma has been associated with lower mortality (22), one major concern of the protocol herein discussed is that we could have used REBOA, even if Mr. Nasar had presented intrathoracic injuries requiring surgery. The use of REBOA in cases of penetrating thoracic trauma is a controversial topic in modern trauma surgery, and current guidelines advise against REBOA deployment when the source of hemorrhage is inside the thorax (38-40). However, this recommendation is theoretical and applies to services such as the emergency department when the precise localization of the intra-thoracic hemorrhage is unknown, the surgical access to the thoracic cavity is not ideal, and the approach with two teams of surgeons is rarely feasible. Blindly occluding the aorta without access to proximal hemorrhage may not be beneficial. In contrast to current recommendations, recent case series from our institution (18,19,21), describing the feasibility and potential utility of deploying REBOA in these scenarios, found no significant differences between the true and the predicted survival rates of hemodynamically unstable patients with penetrating chest injuries and treated with REBOA (19).

Furthermore, data from animal models support the use of REBOA in penetrating thoracic trauma (41,42). For example, Glaser et al. (42) assessed the hemodynamic response to REBOA in a swine model of hemorrhagic shock and penetrating thoracic injuries. After inflicting pulmonary parenchymal, thoracic venous, and subclavian artery injuries and treating them with and

without REBOA, there were no significant differences in the total thoracic blood loss or short term survival between the REBOA and non-REBOA groups. Therefore, there is preclinical data supported by clinical evidence (18,19,41,42) - though it is low quality evidence (case series/Level IV) -, to challenge the current recommendation that REBOA is contraindicated in patients with traumatic thoracic vascular injury and hemorrhage. However, clinical prudence is required when advocating REBOA as a therapeutic tool for these patients. The success in patients with hemorrhage above the diaphragm, as described in the reports from our institution, is due to the support of highly experienced senior surgeons and a two-team approach.

LIMITATIONS

There are some additional limitations to these arguments. First, a single character in the Gabriel García-Marquez's world is not an accurate reflection of the characteristics of the larger population from the universe of magical realism, and certainly even less of the real-world trauma population. Second, as we deliberately assigned both the exposure and outcome to an uncontrolled observation, a formal causal inference is impossible. Third, since Mr. Nasar's hemodynamic status variables (i.e., systolic blood pressure, heart rate) were not reported, we do not know whether he received REBOA according to best practice guidelines (43), or not.

Finally, the writers of this report do acknowledge that they were prone to fall into the trap of "anecdotal fallacy," which is the tendency or temptation to unjustifiably generalize. (44) Thus, we recommend that readers should exercise caution if they find the descriptions and outcomes herein discussed, an implicit statement of the truth.

Despite our limitations, we submit an approach that may help trauma surgeons to better understand how REBOA should be used in a real-world scenario, based on our current knowledge about this intervention.

Therefore, this case report may be shared with appropriate staff for implementation and educational purposes.

This is, to our knowledge, the first report on the use of REBOA in the world created by Gabriel García-Marquez, and using a magical realism narrative. Based on our current knowledge about REBOA in trauma surgery, we claim that its use, coupled with appropriate surgical care for hemorrhage control, could have saved Santiago Nasar's life, thereby preventing a death foretold.

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Authors' Contribution

RMN: conceived the idea and wrote the first draft of the manuscript.

JCY, MPN, JMO and ICH: conducted the literature search.

DMcG, JCP, TMH, EEM and AFG: provided writing assistance and performed a critical revision of the manuscript for relevant intellectual content.

All authors contributed equally to this work. All authors made critical revisions to the manuscript and approved the final version for submission.

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Conflict of interest

The authors declare that they have no conflict of interest to disclose.

Presentations

None declared.

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