

[CASE REPORT]

Successful Management of Resuscitative Endovascular Balloon Occlusion of the Aorta for Hemorrhagic Shock Due to Ruptured Hepatocellular Carcinoma

Haruka Okada^{1,2}, Yuji Koike¹, Shotaro Kishimoto^{1,2}, Kosuke Mori³, Shohei Imaki³,
Ikuro Torii⁴ and Hirokazu Komatsu¹

Abstract:

A 68-year-old man was transferred to our hospital because of sudden right costal pain with unmeasurable hypotension. Ultrasonography revealed possible hemorrhagic shock due to ruptured hepatocellular carcinoma (HCC). As the patient was not hemodynamically stable after primary treatment, resuscitative endovascular balloon occlusion of the aorta (REBOA) was performed, and hemodynamic stability was then achieved. Contrast-enhanced computed tomography confirmed the diagnosis. Transcatheter artery embolization with gelatin sponge particles and coils eliminated the extravasation. The patient was discharged on day 36 post-procedure. Our observations suggest that REBOA may help achieve hemodynamic stability in cases of ruptured HCC.

Key words: resuscitative endovascular balloon occlusion of the aorta, hepatocellular carcinoma, transcatheter arterial embolization

(Intern Med 61: 1157-1162, 2022)

(DOI: 10.2169/internalmedicine.8133-21)

Introduction

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a resuscitation technique used to stabilize hemodynamics in sub-diaphragmatic non-compressible torso hemorrhage. An inflated balloon in the aorta reduces blood flow to the bleeding site and increases the cardiac afterload and proximal aortic pressure, thereby increasing cerebral and myocardial circulation. The REBOA procedure has been accepted worldwide as a less invasive alternative to aortic clamping by resuscitative thoracotomy.

The REBOA procedure involves the insertion of a sheath through the femoral artery and the placement of a catheter into the aorta. The balloon is then inflated in the aorta above the estimated site of bleeding (Fig. 1a). It is safer to insert the balloon under fluoroscopic guidance, but in urgent cases, it is acceptable to insert it without fluoroscopy and

confirm the position by X-ray or ultrasonography prior to balloon dilation. In fact, a previous study using Japanese multi-institutional data showed that 75% of REBOA procedures were performed in the emergency department, with only 17% performed in the angiography suite (1). Contemporary REBOA refers to aorta occlusion within one of the three discrete zones: Zone 1, the descending thoracic aorta between the left subclavian artery and the celiac artery; Zone 2, the aorta from the celiac artery to the lowest renal artery; and Zone 3, the aorta from the lowest renal artery to the aortic bifurcation (2) (Fig. 1b). In patients with intra-abdominal hemorrhage, the balloon is typically placed in Zone 1.

A previous study demonstrated that the mean distance from the femoral artery to the left subclavian artery and the celiac trunk was 56 and 32 cm, respectively (3). Using this as an indicator, external anatomical landmarks, such as the supra-sternal notch or xiphoid process, can also be useful

¹Department of Gastroenterology, Yokohama Municipal Citizen's Hospital, Japan, ²Division of Gastroenterology and Hepatology, Department of Internal Medicine, School of Medicine, Keio University, Japan, ³Department of Emergency and Critical Care Medical Center, Japan and ⁴Department of Diagnostic Radiology, Yokohama Municipal Citizen's Hospital, Japan

Received: June 13, 2021; Accepted: August 11, 2021; Advance Publication by J-STAGE: September 25, 2021

Correspondence to Dr. Haruka Okada, okaharu@keio.jp

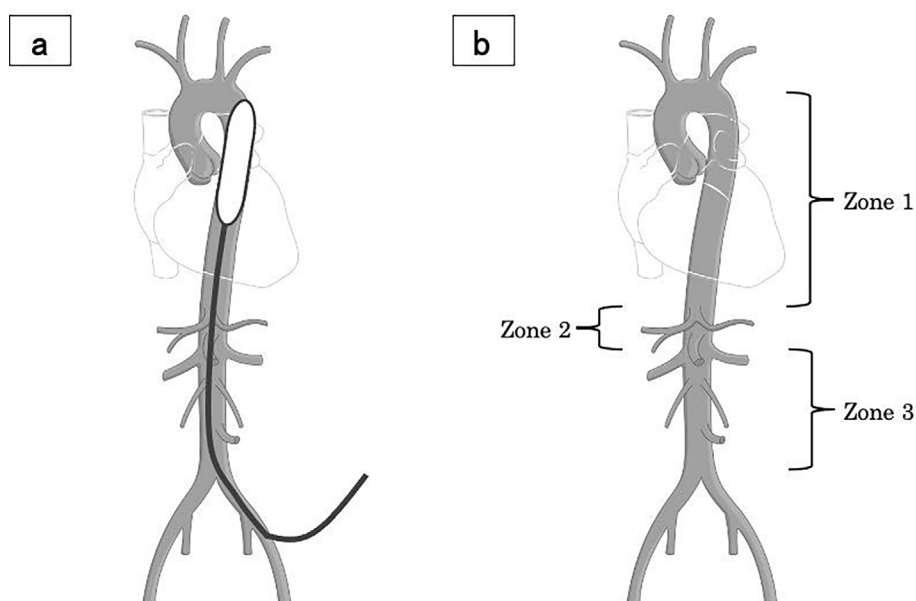


Figure 1. (a) A catheter with a balloon was inserted into the femoral artery, and the balloon was inflated in the aorta. (b) Aortic zones related to REBOA: Zone 1, the descending thoracic aorta between the left subclavian artery and the celiac artery; Zone 2, the aorta from the celiac artery to the lowest renal artery; and Zone 3, the aorta from the lowest renal artery to the aortic bifurcation.

for the safe execution of REBOA in Zone 1 without fluoroscopic guidance.

Initially, REBOA was used in traumatic torso hemorrhage as an alternative to aortic clamping by resuscitative thoracotomy. However, with advances in the technology and products used in REBOA, reports of REBOA use in cases of non-traumatic bleeding have increased.

We herein report a case in which REBOA was used to treat life-threatening hemorrhagic shock in ruptured hepatocellular carcinoma (HCC).

Case Report

A 68-year-old man with no medical history who consumed 60 g of pure alcohol every day was transferred to our hospital because of sudden right costal pain and loss of consciousness for several seconds. On arrival, his Glasgow Coma Score was 13 (E3, V4, M6), and his vital signs were oxygen saturation, 99% on 15 L of oxygen via face mask; heart rate, 101 beats per minute; respiratory rate, 24 breaths per minute; and body temperature, 34.8 °C. His blood pressure could not be measured.

Laboratory tests (Table) showed mild anemia (hemoglobin level, 12.3 g/dL). Abdominal ultrasonography revealed a hepatic tumor, 10 cm in size, with fluid around the liver. Intra-abdominal bleeding due to ruptured HCC was suspected.

The patient was incubated, and extracellular fluid administration was initiated, with the patient receiving another 250 mL of 5% albumin and noradrenaline. The blood pressure was increased temporarily but could not be maintained. The rate of noradrenaline infusion was increased, and 560 mL of red blood cells without cross-compatibility testing and 240

mL of fresh-frozen plasma were started, but the systolic blood pressure repeatedly dropped below 80 mmHg. We diagnosed him with non-traumatic hemorrhagic shock unresponsive to primary treatment and decided to use REBOA.

The patient could not be moved to the angiography suite due to hemodynamic instability, so REBOA was started in the emergency room. A 10-Fr aortic occlusion balloon (Block Balloon[®]; Senko Medical Instrument, Tokyo, Japan) was inserted through the femoral artery using a non-fluoroscopic approach. The position of the balloon was confirmed by portable chest X-ray (Fig. 2). At 63 minutes after arrival at our hospital, the balloon was inflated. The systolic blood pressure of the upper extremity increased to 120 mmHg within 1 minute and stabilized (Fig. 3). The systolic blood pressure of the lower extremities was adjusted to approximately 60 mmHg by regulation of the volume of saline in the balloon. The blood pressure was measured via the arterial line in the femoral artery on the opposite side to the REBOA site.

Since the hemodynamics had been stabilized, the patient was able to be moved from the emergency room. With the temporary deflation of the balloon, contrast-enhanced computed tomography (CT) was performed to diagnose and identify the bleeding source. After the balloon deflation, the systolic blood pressure dropped to approximately 60 mmHg. The balloon was inflated again, and the blood pressure stabilized thereafter. CT revealed multiple tumors in both liver lobes with hyperenhancement in the arterial phase and washout in the delayed phase. We found a tumor measuring 10 cm in diameter in segment 4/8 as well as extravasation of blood inside and around the tumor (Fig. 4). We diagnosed the patient with ruptured HCC with hemorrhagic shock and

Table. Laboratory Data on Arrival.

Peripheral Blood Counts		Biochemistry	
WBC	14,380 / μ L	T-Bil	0.8 mg/dL
Neu	78 %	γ -GTP	245 IU/L
RBC	369 \times 10 ⁴ / μ L	ALP	339 IU/L
Hb	12.3 g/dL	AST	45 IU/L
Ht	37.1 %	ALT	51 IU/L
Plt	26.4 \times 10 ⁴ / μ L	LDH	164 IU/L
		TP	6.6 g/dL
		Alb	3.4 g/dL
		BUN	14.1 mg/dL
		Cr	1.19 mg/dL
		Na	135 mEq/L
		K	3.6 mEq/L
		Cl	99 mEq/L
		CRP	0.2 mg/dL
		Immunology	
		Hyaluronic acid	456 ng/mL
		M2BPGi index	1.49
		HBs-Ag	-
		HCV-Ab	-
		ANA	80 times
		AFP	7.1 ng/mL
		PIVKA-II	1,090 mAU/mL

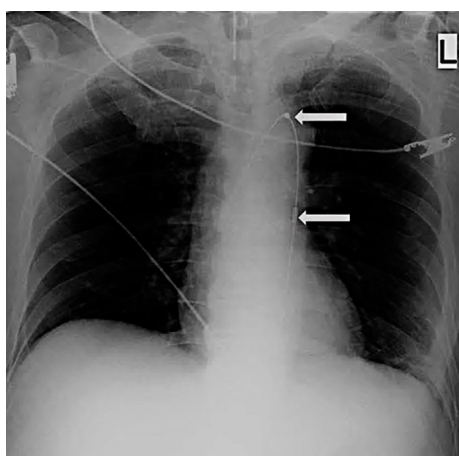


Figure 2. Chest X-ray shows the metallic stilet inside the catheter. Arrows indicate the proximal and distal markers of the balloon.

decided to perform transcatheter artery embolization (TAE).

The patient was moved to the angiography suite. A catheter was inserted through the femoral artery on the opposite side of the REBOA site. At 85 minutes after arrival at the hospital, angiography showed a giant tumor stain, 10 cm in diameter, with extravasation at the edge of the tumor into the abdominal cavity (Fig. 5). Multiple embolization was performed using gelatin sponge particles and coils, resulting in the elimination of extravasation. The balloon was then deflated. Noradrenaline was tapered and was no longer necessary at the end of TAE. The duration of balloon occlusion

amounted to 17 minutes before CT and 62 minutes after CT.

The serum liver enzymes temporarily increased (AST/ALT 505/182 IU/L) with a peak on day 3, which was consistent with the general clinical course post-TAE. There was no organ damage associated with the aortic occlusion. The patient was discharged with good progress on day 36. For 15 months after his discharge, he performed his activities of daily living satisfactorily. He was treated with five sessions of TAE and chemotherapy comprising Atezolizumab plus Bevacizumab. Thereafter, he opted for palliative care due to disease progression.

Discussion

Ruptured HCC is the third-most common cause of death in patients with HCC after tumor progression and liver failure (4). In recent years, mortality due to ruptured HCC has been decreasing with early detection and advanced treatment. Previously in Japan, ruptured HCC was responsible for 10% of mortality among HCC patients and has decreased to 6.4%, as described by a recent report (5). A ruptured HCC has a poor prognosis: at the time of the initial diagnosis, 42-75% of patients are in shock (6), and the 30-day mortality rate is in the range of 30-70% (7). The treatment options for HCC rupture include conservative management, surgical hemostasis, TAE, and emergency/staged liver resection. TAE is the least invasive treatment to achieve hemostasis, with a success rate of 53% to 100% (8). Kirikoshi reported that conservative treatment has a poor prognosis

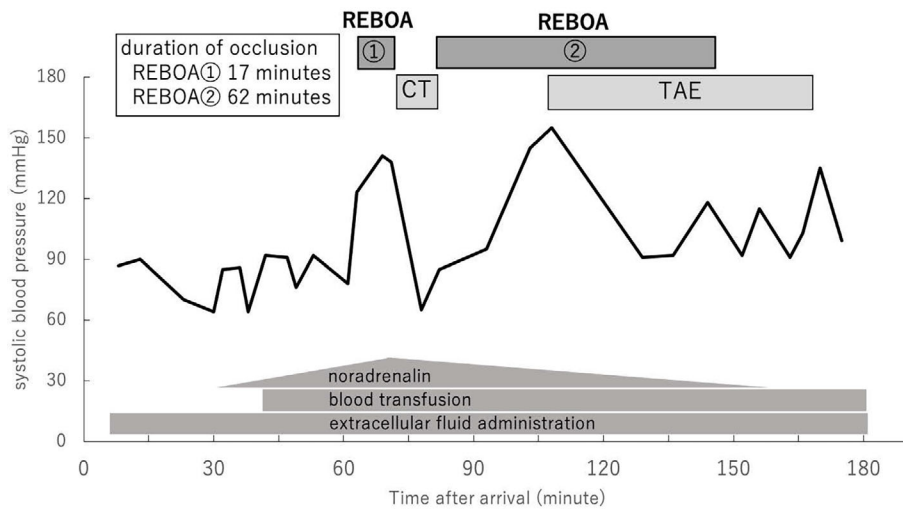


Figure 3. The clinical course of the patient after arrival at the hospital, showing that extracellular fluid administration, noradrenaline administration, and blood transfusion were started sequentially, but the blood pressure did not stabilize. REBOA① was performed, resulting in a rapid increase in blood pressure. After CT, REBOA② was restarted, and TAE was performed. The occlusion time was 17 minutes for ① and 62 minutes for ②.

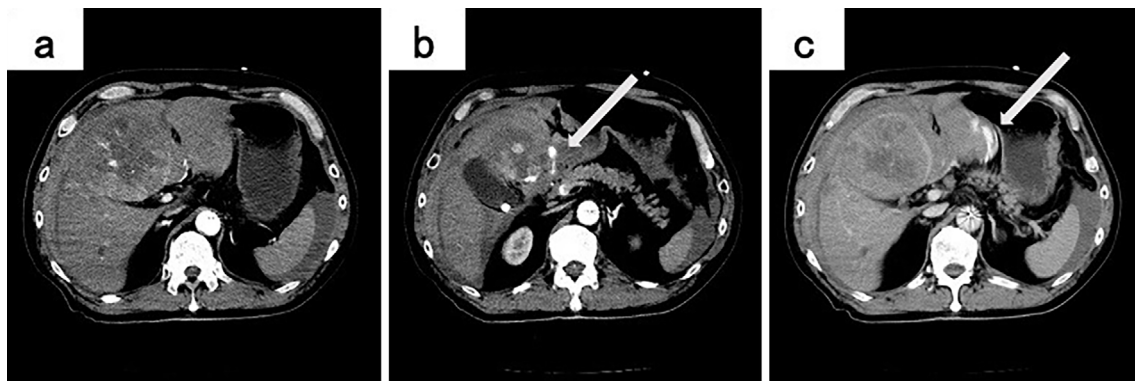


Figure 4. Findings of contrast-enhanced computed tomography. (a) A giant hepatic tumor in segment 4/8 with hyperenhancement in the arterial phase. (b) Extravasation of contrast medium inside the tumor in the arterial phase (arrow). (c) Extravasation of contrast medium around the tumor in the delayed phase (arrow).

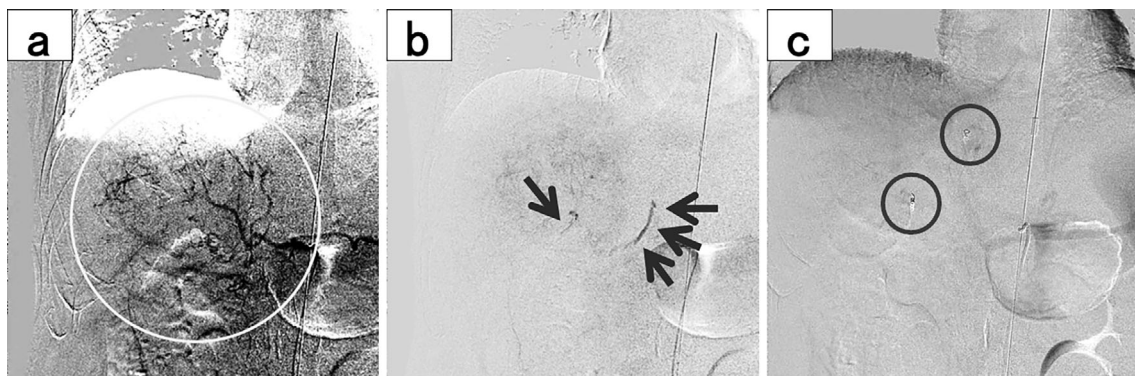


Figure 5. Angiography of the celiac artery revealed a mass (a, circle) with multiple extravasations both inside and outside (b, arrows). After embolization with gelatin sponge particles and coils (c, circle), angiography showed the disappearance of the tumor stain and extravasation.

with a median survival time of 13.1 days, while TAE prolonged the survival to 244.8 days (7). The best treatment for definitive hemostasis is still debatable. Nevertheless, at initial resuscitation, it is necessary to correct hypovolemia resulting from hemorrhage and stabilize the patient (4, 9), making diagnosis and definitive treatment possible.

The REBOA procedure is used to stabilize hemodynamics before definitive hemostasis. In the past, aortic clamping by resuscitative thoracotomy was widely used to reduce bleeding in hemorrhagic shock. The use of intra-aortic balloon occlusion (IABO) for traumatic hemorrhage has been reported since the 1950s (10). However, IABO has been associated with problems, such as a large sheath diameter and migration due to aortic blood flow. To address these issues, REBOA, which is specialized for resuscitation of hemorrhagic shock in IABO, was developed in Japan in 1998. Compared to IABO, REBOA has a smaller sheath diameter. A metallic stylet is placed inside the balloon catheter to prevent balloon migration caused by aortic pressure. In addition, the cylindrical shape of the balloon allows for broad contact with the arterial wall. The REBOA procedure was approved for insurance coverage by the Japanese Ministry of Health in 2000 (11). In addition, a new product with a sheath diameter of 7 Fr became available in 2013. Complications of REBOA include vascular injury, hemorrhage, and lower extremity ischemia, the frequency of which is unreported. However, with the development of products and advances in the execution of REBOA, this technique has become relatively safe to use. In the last 20 years, REBOA has become widely recognized and has also been used not only for trauma cases but also for non-traumatic cases as well, such as in internal medicine and for managing perinatal and postoperative bleeding. In a multicenter retrospective study in Japan, Matsumura reported that the 24-hour survival rate of non-traumatic hemorrhagic shock treated with REBOA was better than that of traumatic hemorrhage. He further mentioned that REBOA might help sustain the hemodynamics more effectively in non-traumatic cases where there is mostly a single source of bleeding than in traumatic cases where there can be multiple sites of bleeding (12). In the field of internal medicine, there have been reports of the use of REBOA for managing gastrointestinal bleeding (13), visceral artery aneurysms (14), and abdominal aortic aneurysms.

In the present case, ruptured HCC was strongly suspected based on the ultrasonography findings obtained soon after patient arrival at the hospital. Even after starting vasopressor and blood transfusion, hemodynamic stability was not achieved. Therefore, the patient could not be moved to the CT room. Without the use of REBOA, CT could not have been performed, and definitive hemostasis could not have been achieved. The management of a ruptured HCC with REBOA and TAE preserved the life of our patient. The REBOA procedure may be a good management strategy for ruptured HCCs with hemorrhagic shock, as it can help stabilize vital signs and help achieve effective hemostasis.

The procedure of REBOA has various advantages over aortic clamping, including being quicker to introduce, less invasive, and easier to handle. The balloon volume can be adjusted by the amount of saline. In REBOA, the degree of balloon dilation and the duration of occlusion can be adjusted to suit the conditions in each case. Furthermore, REBOA can help suppress the blood flow and easily achieve endoscopic hemostasis (13). In our case, temporary deflation of the balloon allowed us to perform contrast-enhanced CT, which helped identify the source of bleeding and thereby achieve hemostasis.

Zhu reported that ruptured HCC was correctly diagnosed by ultrasonography in 66%, CT in 100%, and angiography in only 20% of cases (15). In addition, to confirm active extravasation on angiography, the bleeding rate from the ruptured site should be more than 1 mL/min (16). Based on the above observations, we believe that it is acceptable to perform contrast-enhanced CT to establish a definitive diagnosis before proceeding to definitive hemostasis.

However, while REBOA is useful for stabilizing hemodynamics, there are some issues in clinical settings, as there is no consensus concerning the most appropriate degree of balloon dilation or the optimal duration of occlusion.

First, the difference between complete and partial occlusion has been widely considered in recent years. Complete occlusion occurs when the balloon is inflated until the blood flow in the lower extremity is lost; partial occlusion occurs when the balloon is only partially inflated to maintain blood flow to the lower extremity. Partial occlusion has been reported to be more effective in increasing and maintaining the blood pressure with fewer complications (17, 18); for this reason, partial occlusion was used to treat 70% of the cases in Japan (1). However, there is no clear view as to what indicators should be used to adjust the degree of partial occlusion. In our case, the degree of partial REBOA was adjusted to maintain the blood pressure of the femoral artery at approximately 60 mmHg.

Second, some studies reported that long-term occlusion causes irreversible damage due to ischemia of the lower extremities or organs such as kidneys (19, 20). The duration of occlusion in patients who survived was reportedly shorter than in patients who did not (21). An animal study suggested that mortality increased when the duration of occlusion exceeded more than 40 to 60 minutes (22). This threshold is often used as an upper time limit in clinical settings. In addition, partial occlusion allows for the extension of the occlusion duration (17). In our case, partial occlusion was performed for 17 minutes before and 62 minutes after CT before achieving definitive hemostasis by TAE without any observable adverse events. To use REBOA more effectively, further research will be needed to clarify the appropriate degree of balloon dilation and the optimal duration of occlusion.

The survival rates of patients who underwent REBOA were 39%, 49%, and 60% in 2004-2007, 2008-2011, and 2012-2015, respectively (23). The frequency of REBOA be-

ing used in the treatment of gastroenterological diseases, such as upper gastrointestinal bleeding and ruptured HCC, is expected to increase in the future. In the clinical setting in Japan, most REBOA procedures have been performed by emergency physicians. Internal medicine physicians should consider REBOA as a treatment option and collaborate with emergency physicians to perform the procedure. Further investigations into the benefits of REBOA are necessary.

In conclusion, we encountered a case of a ruptured HCC where the hemodynamics were stabilized by REBOA. In general, ruptured HCC can be fatal. However, in our case, the appropriate use of REBOA and TAE prevented patient death with no adverse events. Clinicians should be aware that REBOA may be useful in treating ruptured HCCs.

Haruka Okada ORCID iD <https://orcid.org/0000-0001-7588-5964>

Yuji Koike ORCID iD <https://orcid.org/0000-0003-2477-2606>

The authors state that they have no Conflict of Interest (COI).

References

- Matsumura Y, Matsumoto J, Kondo H, Idoguchi K, Funabiki T; DIRECT-IABO Investigators. Partial occlusion, conversion from thoracotomy, undelayed but shorter occlusion: resuscitative endovascular balloon occlusion of the aorta strategy in Japan. *Eur J Emerg Med* **25**: 348-354, 2018.
- Stannard A, Eliason JL, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct for hemorrhagic shock. *J Trauma* **71**: 1869-1872, 2011.
- Okada Y, Narumiya H, Ishii W, Iiduka R. Anatomical landmarks for safely implementing resuscitative balloon occlusion of the aorta (REBOA) in zone I without fluoroscopy. *Scand J Trauma Resusc Emerg Med* **25**: 63, 2017.
- Bassi N, Caratozzolo E, Bonariol L, et al. Management of ruptured hepatocellular carcinoma: implications for therapy. *World J Gastroenterol* **16**: 1221-1225, 2010.
- Ikai I, Arai S, Okazaki M, et al. Report of the 17th nationwide follow-up survey of primary liver cancer in Japan. *Hepatol Res* **37**: 676-691, 2007.
- Matsumura Y, Matsumoto J, Idoguchi K, et al. Non-traumatic hemorrhage is controlled with REBOA in acute phase then mortality increases gradually by non-hemorrhagic causes: DIRECT-IABO registry in Japan. *Eur J Trauma Emerg Surg* **44**: 503-509, 2018.
- Kirikoshi H, Saito S, Yoneda M, et al. Outcomes and factors influencing survival in cirrhotic cases with spontaneous rupture of hepatocellular carcinoma: a multicenter study. *BMC Gastroenterol* **9**: 29, 2009.
- Sahu SK, Chawla YK, Dhiman RK, et al. Rupture of hepatocellular carcinoma: a review of literature. *J Clin Exp Hepatol* **9**: 245-256, 2019.
- Lai EC, Lau WY. Spontaneous rupture of hepatocellular carcinoma: a systematic review. *Arch Surg* **141**: 191-198, 2006.
- Hughes CW. Use of an intra-aortic balloon catheter tamponade for controlling intra-abdominal hemorrhage in man. *Surgery* **36**: 65-68, 1954.
- Aoki M, Abe T, Hagiwara S, Saitoh D, Oshima K. Resuscitative endovascular balloon occlusion of the aorta may contribute to improved survival. *Scand J Trauma Resusc Emerg Med* **28**: 62, 2020.
- Fukui T, Mizui S, Kuwabara I, et al. Hemorrhagic shock and respiratory failure in a patient with a ruptured hepatocellular carcinoma treated by intensive care followed by hepatectomy. *JJAAM* **21**: 351-357, 2010.
- Sano H, Tsurukiri J, Hoshiai A, Oomura T, Tanaka Y, Ohta S. Resuscitative endovascular balloon occlusion of the aorta for uncontrollable nonvariceal upper gastrointestinal bleeding. *World J Emerg Surg* **11**: 20, 2016.
- Gabriel O, Keith S, Paul G. Successful use of resuscitative endovascular balloon occlusion of the aorta in the treatment of ruptured 8.5-cm splenic artery aneurysm. *J Vasc Surg* **66**: 1873-1875, 2017.
- Zhu LX, Wang GS, Fan ST. Spontaneous rupture of hepatocellular carcinoma. *Br J Surg* **83**: 602-607, 1996.
- Kim PT, Su JC, Buczkowski AK, et al. Computed tomography and angiographic interventional features of ruptured hepatocellular carcinoma: pictorial essay. *Can Assoc Radiol J* **57**: 159-168, 2006.
- Matsumura Y, Matsumoto J, Kondo H, et al. Fewer REBOA complications with smaller devices and partial occlusion: evidence from a multicenter registry in Japan. *Emerg Med J* **34**: 793-799, 2017.
- Forte DM, Do WS, Weiss JB, et al. Validation of a novel partial resuscitative endovascular balloon occlusion of the aorta device in a swine hemorrhagic shock model: fine tuning flow to optimize bleeding control and reperfusion injury. *J Trauma Acute Care Surg* **89**: 58-67, 2020.
- Saito N, Matsumoto H, Yagi T, et al. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. *J Trauma Acute Care Surg* **78**: 897-903, 2015.
- Otsuka H, Sato T, Sakurai K, et al. Effect of resuscitative endovascular balloon occlusion of the aorta in hemodynamically unstable patients with multiple severe torso trauma: a retrospective study. *World J Emerg Surg* **13**: 49, 2018.
- Tsurukiri J, Akamine I, Sato T, et al. Resuscitative endovascular balloon occlusion of the aorta for uncontrolled haemorrhagic shock as an adjunct to haemostatic procedures in the acute care setting. *Scand J Trauma Resusc Emerg Med* **24**: 13, 2016.
- Avaro JP, Mardelle V, Roch A, et al. Forty-minute endovascular aortic occlusion increases survival in an experimental model of uncontrolled hemorrhagic shock caused by abdominal trauma. *J Trauma* **71**: 720-725, 2011.
- Saito N, Matsumoto H, Yagi T. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. *J Trauma Acute Care Surg* **78**: 879-904, 2015.

The Internal Medicine is an Open Access journal distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).