OPEN

Availability of on-site acute vascular interventional radiology techniques performed by trained acute care specialists: A single–emergency center experience

Junya Tsurukiri, MD, PhD, Shoichi Ohta, MD, PhD, Shiro Mishima, MD, PhD, Hiroshi Homma, MD, PhD, Eitaro Okumura, MD, Itsuro Akamine, MD, Masahito Ueno, MD, Jun Oda, MD, PhD, *and* **Tetsuo Yukioka, MD, PhD***, Tokyo, Japan*

INTRODUCTION: Comprehensive treatment of a patient in acute medicine and surgery requires the use of both surgical techniques and other treatment methods. Recently, acute vascular interventional radiology techniques (AVIRTs) have become increasingly popular, enabling adequately trained in-house experts to improve the quality of on-site care.

METHODS: After obtaining approval from our institutional ethics committee, we conducted a retrospective study of AVIRT procedures performed by acute care specialists trained in acute medicine and surgery over a 1-year period, including those conducted out of hours. Trained acute care specialists were required to be certified by the Japanese Association of Acute Medicine and to have completed at least 1 year of training as a member of the endovascular team in the radiology department of another university hospital. The study was designed to ensure that at least one of the physicians was available to perform AVIRT within 1 h of a request at any time. Femoral sheath insertion was usually performed by the resident physicians under the guidance of trained acute care specialists.

RESULTS: The study sample comprised 77 endovascular procedures for therapeutic AVIRT (trauma, n = 29, and nontrauma, n = 48) among 62 patients (mean age, 64 years; range, 9–88 years), of which 55% were male. Of the procedures, 47% were performed out of hours (trauma, 52%; and nontrauma, 44%). Three patients underwent resuscitative endovascular balloon occlusion of the aorta in the emergency room. No major device-related complications were encountered, and the overall mortality rate within 60 days was 8%. The recorded causes of death included exsanguination (n = 2), pneumonia (n = 2), sepsis (n = 1), and brain death (n = 1).

CONCLUSION: When performed by trained acute care specialists, AVIRT seems to be advantageous for acute on-site care and provides good technical success. Therefore, a standard training program should be established for acute care specialists or trauma surgeons to make these techniques a part of the standard regimen. (*J Trauma Acute Care Surg.* 2017;82: 126–132. Copyright © 2016 the Author(s). Published by Wolters Kluwer Health on behalf of the American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapy/care management study, level V.

KEY WORDS: Endovascular treatment; embolization; trauma surgeon; emergency department; training.

In acute medicine and surgery (AMS), acute care specialists can encounter vascular injuries caused by traumatic hemorrhage, nontraumatic hemorrhage, and embolism. Thus, comprehensive treatment of a patient requires surgical intervention in tandem with other treatments. Since interventional radiology has become increasingly popular, adequately trained in-house radiology experts have been able to improve the quality of on-site care they provide. In addition, with advances in catheter-based techniques and the development of newer embolic agents, acute vascular interventional radiology techniques (AVIRTs) have become an alternative first-line treatment method, particularly when arterial bleeding is located in areas where it is difficult to control such as the lungs, liver, or pelvis.[1] Although we previously reported the advantages of AVIRT for trauma patients when performed by trained trauma surgeons in the emergency department (ED) at Tokyo Medical University, no studies to our knowledge have examined the usefulness of AVIRT for trauma and nontrauma cases when performed by trained acute care physicians and surgeons.[1,2] Therefore, we retrospectively reviewed the records of patients who underwent AVIRT by trained acute care specialists in our emergency center to determine the advantages of AVIRT in acute on-site care.

Submitted: March 26, 2016, Revised: May 16, 2016, Accepted: May 17, 2016, Published online: June 8, 2016.

From the Emergency and Critical Care Medicine (J.T., E.O., I.A.), Tokyo Medical University Hachioji Medical Center; Emergency and Disaster Medicine (S.O., S.M., H.H., J.O., T.Y.), Tokyo Medical University, Tokyo, Japan; and General Surgery (M.U.), Fuchinobe General Hospital, Kanagawa, Japan.

This paper was presented as a quick shot at the 75th annual meeting of the American Association for the Surgery of Trauma and the Clinical Congress of Acute Care Surgery, September 14–17, 2016, in Waikoloa, Hawaii.

Address for reprints: Junya Tsurukiri, MD, PhD, 1163 Tatemachi, Hachioji, Tokyo 193-0998, Japan; email: junya99@tokyo-med.ac.jp.

DOI: 10.1097/TA.0000000000001154

METHODS

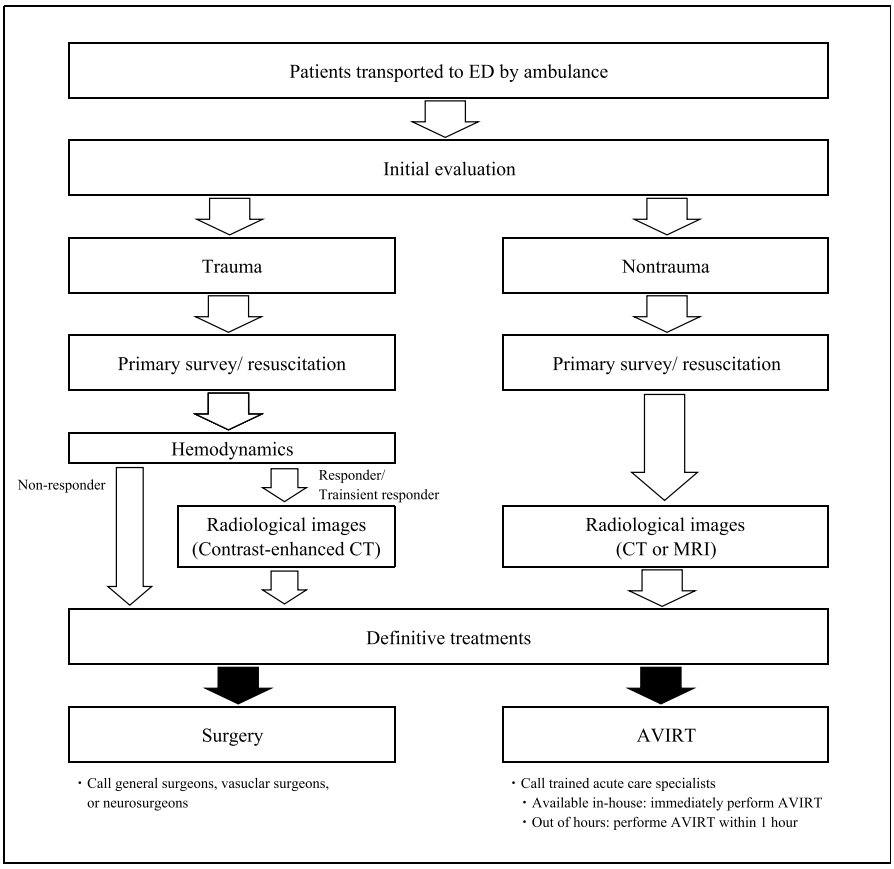
Patients and Study Design

The ethics committee of Tokyo Medical University Hachioji Medical Center approved the design of this retrospective study. We reviewed daily referrals and therapeutic AVIRT procedures performed by trained acute care specialists in AMS over a 1-year period, including out-of-hour procedures.

The emergency center at the Tokyo Medical University Hachioji Medical Center complied with the standards of the American College of Surgeons for a Level II trauma and emergency center.[3] At our hospital, the radiological facilities including three computed tomography (CT) rooms, three magnetic resonance imaging rooms, two coronary interventional suites, and two conventional angiography suites located in front of the ED on the ground floor. The AVIRTs were always performed in the conventional angiography suites. The surgery suite was located on the second floor, and at least one surgeon was available in-house at any given time could be called while performing AVIRT procedures.

Almost all the patients who were transported to our emergency center by ambulance were initially treated by acute care physicians from our ED. Of these patients, those with vascular injuries were allocated to specific treatments (AVIRT, conservative, or surgical treatment) based on the decisions of the attending acute care specialists. These acute care specialists have been certified by the Japanese Association of Acute Medicine (JAAM); for certification, the residents had to complete at least three clinical years in JAAM-accredited education programs and have an evolving specialty with trauma, emergency medicine, and critical care.[4] With these steps, it became clear that the acute care specialists were increasingly responsible for making emergency care decisions in Japan. Based on the judgment of these acute care specialists, surgery for complicated injuries that require more urgent treatment than AVIRT has been given a higher priority.

In this study, we enrolled all patients with vascular injuries who were admitted to our ED and underwent AVIRT by trained acute care physicians. Furthermore, when other departments were immediately unavailable, we performed on-demand AVIRT procedures on in-house patients who needed catheter-based techniques after resuscitation. At any given time, at least one acute care specialist was available in-house; other resident physicians in AMS were also involved in providing care in the ED as well. Therefore, more than two acute care physicians were available in-house every day (24 hours a day, 365 days a year), and one of them could call the trained acute care specialist if necessary. All AVIRT procedures were performed by trained acute care specialists who had completed at least 1 year of training as a member of an endovascular team in the radiology department of a high-volume hospital. Physician coverage was arranged in such a way that at any given time, one of the trained acute care specialists was available as an attending physician and perform AVIRT within 1 hour of the decision approving the procedure (i.e., 24-hour coverage) (Fig. 1). Femoral sheath insertion was usually performed by the residents under the guidance of trained acute care specialists.



AVIRT, acute vascular interventional radiology techniques; CT, computed tomography, ED, emergency department; and MRI, magnetic resonance image

Figure 1. Workflow of AVIRT activation at the ED.

Indications for AVIRT Procedures

Hemorrhage

Angiography was performed when the patient was hemodynamically stable after the initial resuscitation in patients with hepatic, splenic, or renal injuries that were classified as a CT Grade III or higher according to the American Association for the Surgery of Trauma as previously described.[1] For hemodynamically stable patients with pelvic injuries, angiography was performed when contrast medium (CM) extravasation was observed in an extrapelvic hematoma or a large hematoma compressing the bladder was seen even if no extravasation was apparent on CT scan.[2] We also performed angiography following pelvic packing when a fracture was identified on a pelvic x-ray even in cases of hemodynamic instability. In patients with an intracranial hematoma and cranial or facial fractures or with recurrent subdural hematoma who had a severe coagulopathy on anticoagulants, we secured endovascular hemostasis with a middle meningeal artery embolization after a consultation with the neurosurgeons before any conservative or surgical treatment.[5,6] When an angiography showed CM extravasations or pseudoaneurysms from arterial injuries caused by solid organ injuries, pelvic fractures, or other injuries, the trained acute care specialists performed a therapeutic AVIRT.

When excessive bleeding led to hemorrhagic shock or acute respiratory failure in nontrauma patients (e.g., hemoperitoneum or hemoptysis), we performed angiography after the initial resuscitation. Furthermore, an AVIRT procedure was performed in cases of nonvariceal gastrointestinal bleeding (GIB) when an emergency endoscopy failed or when the site of bleeding was difficult to access (e.g., small intestine or colon).[7,8] We routinely performed vascular evaluations using contrast-enhanced CT scans. Furthermore, when angiography showed CM extravasations or pseudoaneurysms from arterial injuries, a trained acute care specialist performed a therapeutic AVIRT.

Ischemia

We performed AVIRT based on the recommendations from the American Heart Association/American Stroke Association Guidelines for ischemic stroke.[9] Acute vascular interventional radiology technique could only be considered for patients who were hemodynamically stable and who did not have clinical signs of advanced intestinal ischemia (e.g., radiographic signs or peritonitis).[10] Patients with ischemia but a viable extremity on clinical examination underwent either AVIRT or surgery for revascularization.[11] For the patients who underwent AVIRT, there was a low threshold for termination of the procedure in cases of complications or for conversion to surgery if the patient's clinical condition deteriorated at any time.

Resuscitative Endovascular Balloon Occlusion of the Aorta

Resuscitative endovascular balloon occlusion of the aorta (REBOA) has been found to successfully elevate central blood pressure in patients with hemorrhagic shock in various clinical setting.[12–14] Therefore, we performed REBOA procedures in patients who had hemodynamic instability and an inability to remain normotensive following resuscitation. This procedure was not routinely used, and the details of REBOA indications and procedures have been previously described.[12]

Data Collection

The following characteristics were noted from the charts and radiographs of all patients: age, sex, clinical history, hemorrhagic severity, AVIRT details, use of REBOA procedures, device-related complications, and outcomes. The major device-related complications included major vessel injuries (e.g., arterial dissection, rupture, or perforation), embolization, air emboli, and peripheral ischemia, whereas minor complications included small artery injuries (e.g., groin pseudoaneurysms, vascular iatrogenic injuries that were amenable to endovascular treatments, or lower limb ischemia at the puncture site).

RESULTS

Descriptive Analysis in Our Cohort

The patients' demographics and clinical characteristics are shown in Table 1. This study comprised 77 therapeutic AVIRT

TABLE 1. Clinical Characteristics of the Patients

Characteristics			
Age, median (IQR), years	64 (56–76)	Procedures of AVIRT, n (%)	
Male, n (%)	55	Embolization	59 (77)
Patient's location, n (%)		Trauma	29 (38)
In-hospital	3 (4)	Nontrauma	30 (51)
Transfer from another hospital	1 (2)	Mechanical retrieval and revascularization	15 (19)
Time of procedures, n (%)		Others	
Daytime	41 (53)	Angioplasty	2 (3)
Out of hours	36 (47)	Drug infusion	1 (2)
Hemorrhagic shock, n (%)	46 (60)	Mortality, n (%)	
Type of acute care, n (%)		Exsanguination	2 (3)
Trauma	29 (38)	Pneumonia	2 (3)
Nontrauma	33 (43)	Sepsis	1 (2)
Stroke	15 (19)	Brain death	1 (2)

IQR, interquartile range; n, number of patients.

TABLE 2. Details of the Acute Vascular Interventional Radiology Techniques

Trauma (n = 29)	n	Nontrauma (n = 48)	n
Embolization (coil, gelfoam, or NBCA)		Embolization (coil, gelfoam, PVA, or NBCA)	
Abdomen		Gastrointestinal bleeding	13
Renal injury	6	Hemoptysis	4
Splenic injury	5	Retroperitoneal hemorrhage	3
Hepatic injury	1	Hemothorax (internal thoracic artery aneurysm)	2
Pelvis		Hemoperitoneum	2
Pelvic injury	5	Peritumoral hemorrhage	
Chest		Hepatic cell carcinoma	2
Intercostal artery (multiple)	1	Pelvic sarcoma	1
Postoperative bleeding		Mediastinal hemorrhage	1
Retroperitoneal hemorrhage (vertebral surgery)	2	Atonic postpartum hemorrhage	1
Delayed bleeding		Internal iliac artery pseudoaneurysm	1
Kidney/Spleen	3	Mechanical retrieval and recanalization	
Head trauma		Stroke	15
Epidural hematoma	2	Others (angioplasty or drug injection)	
Vertebral artery dissection	2	Radial artery embolus	1
Carotid cavernous fistula	1	Superior mesenteric artery occlusion	1
Chronic subdural hematoma	1	Iliac artery stenosis	1

PVA, polyvinyl alcohol particles.

procedures (trauma, n = 29; and nontrauma, n = 48) in 62 patients. The mean age was 64 years (range, 9–88 years), and 55% of the participants were male and 45% were female. The details of the AVIRT procedures are noted in Table 2; of the 77 procedures, 75% were for arterial embolization, and 47% were out-of-hours (trauma, 52%; and nontrauma, 44%). Three patients underwent REBOA in the ED.

Acute Vascular Interventional Radiology Technique Procedures

In this study, we inserted the artery sheath into the femoral artery for all cases. For the AVIRT procedures, 4 Fr gauge sheathless guide catheters (Parent, Medikit, Tokyo, Japan) and 6 Fr sheaths (Terumo, Tokyo, Japan) were used for torso vessel injuries, and 4 Fr Shepherd hook catheters (Terumo, Tokyo, Japan) were used in patients with chest vessel injuries. In patients with a single pelvic injury, internal artery injuries, and retroperitoneal hemorrhage, we used 4 Fr Cobra catheter (Gadelius Medical, Tokyo, Japan) and 5 Fr sheaths. In head trauma, 6 Fr guiding catheters (Fubuki, Asahi Intecc, Aichi, Japan, or Launcher, Medtronic Inc, Minneapolis, USA) and 6 Fr sheaths were used.

In stroke patients, 8 or 9 Fr. balloon guiding catheters (Optimo, Tokai Medical Products, Aichi, Japan) and 9 Fr femoral artery sheaths (Medikit, Tokyo, Japan) were used in 12 cases, and 6 Fr sheathless guide catheters (Fubuki, Asahi Intecc, Aichi Japan) were used in three cases.

The treatment materials included detachable microcoils, gelfoam (Serescue, Nihonkasei, Tokyo, Japan), and *N*-butyl-2-cyanoacrylate (NBCA) (Histoacryl, Braun, Melsungen, Germany) for trauma cases, and detachable microcoils, gelfoam, NBCA, and polyvinyl alcohol particles (Embosphere, Nihonkasei, Tokyo Japan) for nontrauma cases. For other vessel occlusions, we performed balloon angioplasties for severe iliac artery stenosis, drug infusions for intestinal ischemia, and thrombectomies for radial artery emboli. We routinely performed selective catheterization with microcatheters using a coaxial or triaxial system, and our treatment materials were introduced via the microcatheters. For mechanical thrombectomies, we used the Penumbra MAX System (Penumbra Inc, Alameda, CA) in all stroke patients.

Outcomes

No major device-related complications were encountered, but one patient who had a splenic injury had an arterial dissection at a branch of the splenic artery caused by microguidewire handling; this patient also required endovascular coil embolization. We also identified one case of mild necrosis (gluteal) that occurred after embolization in a patient with an unstable pelvic fracture. The overall mortality rate at 60 days was 8% (trauma, 10%; and nontrauma, 6%), with death causes by exsanguination (n = 2), pneumonia (n = 2), sepsis (n = 1), or brain death (*n* = 1).

DISCUSSION

Active hemorrhage is a major cause of death among patients admitted to emergency centers and intensive care units, and initial resuscitation is a high priority for acute hemorrhage in hemorrhagic shock. In this context, interventional radiology with minimally invasive catheter-based techniques is becoming an increasingly essential part of modern medicine.

A single well-trained acute care surgeon can manage both general surgery and trauma surgery in the EDs of hospitals in the United States and, if trained, could also perform endovascular emergency care.[15] However, in Japanese emergency centers, acute care surgeons are not always available, and it can be impractical to wait for general surgeons. Furthermore,

if in-house radiologists are performing scheduled endovascular treatments, AVIRT may not be available immediately, and there can be a significant delay in receiving acute endovascular procedures. This is also complicated by the long time required to contact and wait for radiologists, especially when requested out of hours. In our center, approximately 50% of therapeutic AVIRT procedures were performed out of hours, which is consistent with the reported rate by Ono et al.[16] In a study by Ashleigh et al.[17] in Manchester, 70% of emergency endovascular procedures took place at the weekend. The improvement of workflow in acute care and the growing role of catheter-based techniques in AMS is a matter of continual worldwide development.[18] Thus, by necessity, we have adopted an approach that allows diagnostic and therapeutic AVIRT procedures to be performed by trained acute care specialists for both trauma and nontrauma patients.[1,2]

Brenner et al.[15] reported that they were concerned that interventionalists who were unfamiliar with AMS and injury dynamics may persist in treating clinically insignificant injuries in patients who need other therapy more urgently or who may be best served by stopping the interventional procedure and resuming resuscitation. Matsumoto et al.[18] suggested the importance of radiologists with trauma experience in the initial acute care of hemodynamically unstable trauma patients. This supports our concept that AVIRT should be performed by trained acute care specialists in AMS.

In our experience, GIB is one of the most common nontrauma indications for AVIRT. Although endoscopic treatment is generally acceptable for GIB, it can be difficult to achieve complete success in some patients, and severe hemorrhage can be rapidly fatal. Indeed, it is reported that in 5% to 10% of patients with nonvariceal GIB, it is impossible to achieve hemostasis endoscopically. A recent study indicated that arterial embolization had become a first-line option when managing acute GIB that is refractory to endoscopic hemostasis and surgery.[7,8] Furthermore, a recent systematic review reported that REBOA successfully elevated central blood pressure in patients with hemorrhagic shock in various clinical settings.[13] In this study, three patients (one trauma and two nontrauma patients) underwent REBOA in the ED that was performed by residents trained in femoral sheath insertion by trained acute care specialists. Resuscitative endovascular balloon occlusion of the aorta is an important adjunct procedure designed to sustain the circulation until definitive hemostasis can be obtained. This procedure is a newer catheter-based technique, and we previously reported that our trained acute care physicians could complete REBOA procedures with a high degree of technical success.[12]

There has been marked progress in the development of embolic agents over the past decade, with a variety of materials now available, including metallic coils, gelatin sponge particles, liquids, and nitinol plugs. Patients with hemorrhage often develop coagulopathy, and the resulting uncontrolled hemorrhage is often associated with poor outcomes, regardless of whether the case is of traumatic or nontraumatic in origin. Recently, NBCA has been used as a liquid embolic agent in various nontraumatic situations, where it has been shown to have a high technical success rate and low recurrent bleeding rate, especially in patients with coagulopathy.[19] Although the use of gelatin sponge particles remains popular because of its easier handling, a recent study reported that NBCA was more effective in an animal model of hemorrhage-induced coagulopathy.[20] There have also been a few case reports of successful use of NBCA in trauma patients, and it seems to be the most effective method in cases of severe trauma.[16] However, some training is needed for the use of NBCA because of the risk of ischemic complications or reflux, and the need to handle it safely. Thus, we conduct training in our radiology department to practice handling these embolic agents, who may help achieve successful hemostasis in future trauma resuscitation.

Device-related complications were caused during the insertion of the catheter or artery sheath. Those complications typically associated with catheter insertion are vessel injury (e.g., arterial dissection, rupture, and perforation), embolization, air emboli, and peripheral ischemia, and those associated with sheath insertion are arterial injury (e.g., pseudoaneurysm, arteriovenous fistula, and dissection) and lower limb ischemia at the same site. Despite the acute care setting, we must ensure that we inform patients or their guardians about these complications. In this study, we encountered an iatrogenic splenic artery injury, which was caused by a handling error of a microguidewire that required endovascular coil embolization. We also encountered one case of mild gluteal necrosis after an AVIRT in a patient with an unstable pelvic fracture (traumatic). This was caused by either NBCA embolization or ischemia after catheterization for uncontrolled bleeding from a lateral sacral artery. There were considered device-related complications. We routinely inserted the artery sheath at the femoral artery, except in the case of abdominal aortic aneurysm or other aortic disease, when we used the brachial artery. We also routinely used a calcium alginate hemostasis pad (Tricell, Alliance Medical Group, Tokyo, Japan) for sheath removal to prevent groin hematoma. Trained acute care specialists or trauma surgeons who perform angiography should also be aware of the need to minimize radiation exposure and prevent associated complications, as previously reported.[1,2]

In Japan, the JAAM is committed to residents having to complete at least three clinical years in JAAM-accredited education programs, which are different from those in other developed countries. However, there is a recognition of the need to incorporate training for catheter-based techniques among acute care specialists or trauma surgeons, consistent with the recommendation of Brenner et al.,[15] and we have been practicing these at high-volume trauma or emergency centers. Although the optimal interval for radiology training is difficult to assess, our experience is that 6 months or more are sufficient in high-volume centers. We would also recommend that interventional radiology be performed weekly for at least 6 months with radiologists from the current hospital to ensure continued competency after training has been completed, especially in low-volume emergency centers. The use of catheter-based techniques in the management of whole-body vessel injuries has increased in AMS; there is a role for the training of acute care specialists, trauma surgeons, or intensivists in AVIRT. In Japan, trained acute care specialists recently organized the Society of Diagnostic and Interventional Radiology in Emergency, Critical Care, and Trauma to expand the training on the appropriate use of diagnostic and interventional radiology in emergency

and critical care not only to acute care physicians but also to trauma surgeons, cardiovascular surgeons, and intensivists.[21] In our department, all acute care specialists have trained in critical care medicine through a Japanese Society of Intensive Care Medicine–accredited education program for at least 3 months, and one trained acute care specialist completed one of the Japanese Society for Neuroendovascular Therapy–accredited education programs after the completion of AVIRT training. Some trained acute care specialists have started an acute care surgery training program. We believe that there may be advantages for acute care specialists having significant knowledge about catheter-based techniques in AMS before beginning their training for acute care surgery or critical care medicine.

There are several limitations to this study, most notably the retrospective design and relatively small number of cases. The most notable weaknesses were the use of a post hoc hypothesis, and that AVIRT by trained acute care specialists was not assessed in a randomized trial against controls. In addition, patients were allocated to treatments at the discretion of the attending acute care specialist, so we cannot exclude the possibility of bias.

CONCLUSION

Acute vascular interventional radiology technique performed by trained acute care specialists produced good technical success, making it useful and advantageous for acute on-site care. We recommended these techniques be added to the training requirements of acute care physicians and surgeons.

AUTHORSHIP

T.J. conceived of this study. T.J. and H.H. contributed to the study's design. T.J., O.E., and A.I. performed data collection. T.J., M.S., O.J., and O.S. contributed to data analysis. T.J., O.E., A.I., H.H., M.S., O.J., O.S., and Y.T. participated in data interpretation. T.J., H.H., and O.S. wrote the manuscript. All authors read and approved the final manuscript, the final version of which Y.T. gave final approval for submission.

ACKNOWLEDGMENT

The authors thank Enago (www.enago.jp) for the English language review.

DISCLOSURE

The authors declare no conflicts of interest. This manuscript has not been published previously and is not under consideration for publication elsewhere.

REFERENCES

1. Morozumi J, Ohta S, Homma H, Sasaki H, Oda J, Suzuki K, Ohtaka Y, Noda M, Mishima S, Yukioka T. Introduction of mobile angiography into the trauma resuscitation room. *J Trauma*. 2009;67(2):245–251.
2. Morozumi J, Homma H, Ohta S, Noda M, Oda J, Mishima S, Yukioka T. Impact of mobile angiography in the emergency department for controlling pelvic fracture hemorrhage with hemodynamic instability. *J Trauma*. 2010; 68(1):90–95.
3. American College of Surgeons Committee on Trauma. Resources for optimal care of the injured patient. 2014. Available at: https://www.facs.org/quality%20programs/trauma/vrc/resources. Accessed March 10, 2016.
4. Japanese Association for Acute Medicine. Mission Statement. Available at: http://www.jaam.jp/html/english/english-top.htm. Accessed April 2, 2016.
5. Tempaku A, Yamauchi S, Ikeda H, Tsubota N, Furukawa H, Maeda D, Kondo K, Nishio A. Usefulness of interventional embolization of the middle meningeal artery for recurrent chronic subdural hematoma: five cases and a review of the literature. *Interv Neuroradiol*. 2015;21(3): 336–371.
6. Lammy S, McConnell R, Kamel M, Rennie I, Al-Haddad S. Extradural haemorrhage: is there a role for endovascular treatment? *Br J Neurosurg*. 2013;27(3):383–385.
7. Lee HH, Park JM, Chun HJ, Oh JS, Ahn HJ, Choi MG. Transcatheter arterial embolization for endoscopically unmanageable non-variceal upper gastrointestinal bleeding. *Scand J Gastroenterol*. 2015;50(7):809–815.
8. Kyaw M, Tse Y, And D, Ang TL, Lau J. Embolization versus surgery for peptic ulcer bleeding after failed endoscopic hemostasis: a meta-analysis. *Endosc Int Open*. 2014;2(1):E6–E14.
9. Jauch EC, Saver JL, Adams HP Jr, Bruno A, Connors JJ, Demaerschalk BM, Khatri P, McMullan PW Jr, Qureshi AI, Rosenfield K, Scott PA, Summers DR, Wang DZ, Wintermark M, Yonas H; American Heart Association Stroke Council; Council on Cardiovascular Nursing; Council on Peripheral Vascular Disease; Council on Clinical Cardiology. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/ American Stroke Association. *Stroke*. 2013;44(3):870–947.
10. Jia Z, Jiang G, Tian F, Zhao J, Li S, Wang K, Wang Y, Jiang L, Wang W. Early endovascular treatment of superior mesenteric occlusion secondary to thromboemboli. *Eur J Vasc Endovasc Surg*. 2014;47(2):196–203.
11. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, Hiratzka LF, Murphy WR, Olin JW, Puschett JB, Rosenfield KA, Sacks D, Stanley JC, Taylor LM Jr, White CJ, White J, White RA, Antman EM, Smith SC Jr, Adams CD, Anderson JL, Faxon DP, Fuster V, Gibbons RJ, Hunt SA, Jacobs AK, Nishimura R, Ornato JP, Page RL, Riegel B. American Association for Vascular Surgery; Society for Vascular Surgery; Society for Cardiovascular Angiography and Interventions; Society for Vascular Medicine and Biology; Society of Interventional Radiology; ACC/AHA Task Force on Practice Guidelines Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease; American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; Vascular Disease Foundation. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. *Circulation*. 2006;113(11):e463–e654.
12. Tsurukiri J, Akamine I, Sato T, Sakurai E, Okumura E, Moriya M, Yamanaka H, Ohta S. 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*. 2016;24(1):13.
13. Morrison JJ, Galgon RE, Jansen JO, Cannon JW, Rasmussen TE, Eliason JL. A systematic review of the use of resuscitative endovascular balloon occlusion of the aorta in the management of hemorrhagic shock. *J Trauma Acute Care Surg*. 2016;80(2):324–334.
14. Okumura E, Tsurukiri J, Oomura T, Tanaka Y, Oomura R. Partial resuscitative endovascular balloon occlusion of the aorta as a hemorrhagic shock adjunct for ectopic pregnancy. *Am J Emerg Med*. Epub February 12, 2016.
15. Brenner M, Hoehn M, Teeter W, Stein D, Scalea T. Trading scalpels for sheaths: Catheter-based treatment of vascular injury can be effectively performed by acute care surgeons trained in endovascular techniques. *J Trauma Acute Care Surg*. 80(5):783–786.
16. Ono Y, Ishida T, Iwasaki Y, Kawakami Y, Inokuchi R, Tase C, Shinohara K. The off-hour effect on trauma patients requiring subspecialty intervention at

a community hospital in Japan: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med*. 2015;23:20. doi: 10.1186/s13049-015-0095-1.

17. Ashleigh RJ, Butterfield JS, Asquith J, Chalmers N, Murphy G. A cross-site vascular radiology on-call service: the Manchester experience. *Clin Radiol*. 2005;60(3):389–393.
18. Matsumoto J, Lohman BD, Morimoto K, Ichinose Y, Hattori T, Taira Y. Damage control interventional radiology (DCIR) in prompt and rapid endovascular strategies in trauma occasions (PRESTO): a new paradigm. *Diagn Interv Imaging*. 2015;96(7–8):687–691.
19. Yata S, Ihaya T, Kaminou T, Hashimoto M, Ohuchi Y, Umekita Y, Ogawa T. Transcatheter arterial embolization of acute arterial bleeding in the upper and lower gastrointestinal tract with N-butyl-2-cyanoacrylate. *J Vasc Interv Radiol*. 2013;24(3):422–431.
20. Yonemitsu T, Kawai N, Sato M, Sonomura T, Takasaka I, Nakai M, Minamiguchi H, Sahara S, Iwasaki Y, Naka T, et al. Comparison of hemostatic durability between N-Butyl Cyanoacrylate and gelatin sponge particles in transcatheter arterial embolization for acute arterial hemorrhage in a coagulopathic condition in a swine model. *Cardiovasc Intervent Radiol*. 2010;33(6):1192–1197.
21. The society of DIRECT (Diagnostic and Interventional Radiology in Emergency, Critical Care, and Trauma). Organization Summary. Available at: http://direct.kenkyuukai.jp/about/. Accessed April 5, 2016.