Injury, Int. J. Care Injured xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Use of interventional radiology as initial hemorrhage control to improve outcomes for potentially lethal multiple blunt injuries

Hiroyuki Otsuka*, Toshiki Sato, Keiji Sakurai, Hiromichi Aoki, Takeshi Yamagiwa, Shinichi Iizuka, Sadaki Inokuchi

Department of Emergency and Critical Care Medicine, Tokai University School of Medicine, 143 Shimokasuya, Isehara-City, Kanagawa 259-1193, Japan

ARTICLE INFO

Keywords:
Interventional radiology
Severe trauma management
Damage control strategy
Trauma specialist

ABSTRACT

Introduction: Recently, trauma management has been markedly improved with interventional radiology (IVR) and damage-control strategies. However, the indications for its use in hemodynamically unstable patients with severe trauma remains unclear. In some cases, IVR may be more effective than surgery for damage-control hemostasis; however, performing IVR in life-threatening trauma settings is challenging. To address this, we practiced and evaluated a trauma-management system with emergency physicians who trained for both severe trauma management, and techniques of surgery and IVR.

Materials and methods: Among the 1822 patients with severe trauma admitted between October 2014 and December 2016, 201 underwent emergency surgery or IVR. Among these, 16 patients whose systolic blood pressure was $\leq$90 mmHg, without improvement following primary resuscitation, and whose first intervention was IVR, were analyzed. We retrospectively evaluated the admission characteristics, IVR-related characteristics, and prognoses, and compared several parameters before and after IVR.

Results: This study included 10 men and 6 women (median age: 46 years). IVR was performed for 10 pelvic fractures; five liver-, one splenic-, and one renal injury; and one transection each of the external carotid-, vertebral-, axillosubclavian-, intercostal-, and lumbar arteries. The mean times from the patient arrival, and diagnosis to the start of IVR were 56.3 ± 26.6 and 15.1 ± 3.8 min, respectively. The mean time spent in the angiography suite was 50 min. The systolic blood pressure, pulse rate, base excess/deficit, serum-lactate levels, and D-dimer values were significantly improved after IVR. Although two patients needed additional treatment for morbidities following IVR intervention, all achieved complete recovery. The mortality rate was 25.0%, and no preventable deaths were noted. Eight patients showed unexpected survival.

Conclusions: In some cases, IVR may be the best first measure for resuscitative hemostasis in potentially lethal multiple injuries, given efficient diagnoses/actions and the ability to deal with complications.

Introduction

Recently, interventional radiology (IVR) has been actively introduced into trauma management [1]; however, the indications for its use in hemodynamically unstable patients with severe trauma remain unclear. Today, the use of damage-control strategies for severe trauma patients has become widespread [2–5], although the appropriate integration of IVR into these strategies remains unclear [6,7]. Most guidelines still recommend surgery, not IVR, to be selected for hemodynamically unstable trauma patients, and state that IVR should be performed in patients without blood-flow issues, or as an additional intervention following damage-control surgery [8–11].

Conversely, resuscitative endovascular balloon occlusion of the aorta (REBOA) [12,13] is currently widely used [14]. Furthermore, because computed tomography (CT) scanning, mobile angiography [15,16], and hybrid trauma operating rooms [17,18] have been introduced into emergency departments in recent years, it is now possible to reduce the resuscitation time. Thus, we expect that use of IVR in the trauma setting will expand, and that further developments in the IVR technology will be made. Therefore, we consider that the use of IVR as resuscitative hemostasis may improve the outcomes of hemodynamically unstable trauma patients. In contrast, if a condition exists, resuscitative surgery for diagnosis and treatment prior to adequate examination is

* Corresponding author.
E-mail addresses: hirootsu@is.icc.u-tokai.ac.jp (H. Otsuka), satoshiki1108@gmail.com (T. Sato), sakurai_kyh@yahoo.co.jp (K. Sakurai), h.aoki@is.icc.u-tokai.ac.jp (H. Aoki), yamagiwa@tsc.u-tokai.ac.jp (T. Yamagiwa), eriizuka@hotmail.com (S. Iizuka), inokuchi@is.icc.u-tokai.ac.jp (S. Inokuchi).

https://doi.org/10.1016/j.injury.2017.11.038
0020-1383/

necessary. In the current strategy for severe multiple traumas, we believe that discretion is necessary to ensure prompt and seamless resuscitative treatment, which may consist of only surgery, only IVR, or a combination of both.

To address these issues and to make the best use of surgery or IVR, our institution employs trained emergency physicians (TEPs) who are trained not only in severe trauma management but also in surgical techniques and IVR. Thus, we are able to perform both surgery and IVR immediately and precisely by utilizing the angiography suite and operating room in our emergency department.

In the present study, we aimed to evaluate the efficacy of IVR performed by TEPs for treating patients with life-threatening trauma.

Materials and methods

A total of 1822 patients with severe trauma were admitted to our hospital from October 2014 to December 2016. Among these, emergency surgery and/or IVR were performed for 201 patients. The patients with cardiac arrest at the time of paramedic arrival, or with complicated severe chronic diseases were excluded. For this study, 16 patients whose systolic blood pressure (SBP) had dropped to 90 mmHg or below, without improvement following primary resuscitation, and who had received IVR as the first treatment for resuscitative hemostasis were selected. Inclusion criteria for performing IVR was based on TEPs in the emergency department deciding that performing IVR first was superior to surgery in controlling the main causes of hemorrhage (based on CT findings). Exclusion criteria included CT findings, which indicated that performing IVR would be difficult, such as advanced arteriosclerosis, a large aneurysm, or an anatomical abnormality. The ability to remain motionless was also important. CT scanning was performed on a Siemens Somatom Definition AS+ (Siemens Munich, Germany), and IR was performed on an Allura Xper FD20 (Phillips, Amsterdam, The Netherlands).

We retrospectively evaluated the patient features, including the severity of trauma, hematological tests at the time of admission, surgery/IVR-related characteristics, mortality, and unexpected survival rates. Subsequently, we compared the vital signs and laboratory data before and after IVR. We used Trauma and Injury Severity Score (TRISS) methodology to determine unexpected survivors. The statistical analysis was performed using SPSS version 22.0 for Windows (SPSS, Inc., Chicago, IL, USA). Values are presented as either the mean ± standard deviation or the median. Continuous variables were compared by using either Student's *t*-test or the Mann-Whitney *U* test.

Ethics considerations: This study conforms to the tenets of the Declaration of Helsinki and has been approved by Tokai University School of Medicine's Ethics Committee (approval number 17-032).

Results

This study included 10 men and 6 women aged 6–77 years (median age: 46 years). The causes of trauma were nine traffic accidents, six falls, and one compression. The mean vital signs upon admission were as follows: Glasgow coma scale, 11.1 ± 5.1; SBP, 75.1 ± 21.9 mmHg (lowest SBP before IVR, 47.3 ± 29.4 mmHg); and pulse rate, 112.2 ± 26.7 beats/min. The laboratory data upon admission showed base excess/deficit, −9.0 ± 7.6 mmol/L; serum lactate level, 56.3 ± 42.9 mg/dL; and D-dimer, 88.1 ± 66.4 μg/mL. The mean revised trauma score (RTS), injury severity score (ISS), and probability of survival (Ps) by the TRISS method were 5.3 ± 2.1, 48.6 ± 14.6, and 34.2 ± 30.1, respectively.

All patients underwent CT scanning before IVR. Moreover, procedures performed before IVR included 11 chest drainages (68.8%), 10 endotracheal intubations (62.5%), and 4 REBOAs (25.0%). The median amounts of blood products transfused before IVR were 560 ml of red blood cells and 240 ml of fresh frozen plasma. As above, we performed massive transfusion and permissive hypotension according to damage control strategies pre-IVR. Injuries for which IVR was performed included 10 pelvic fractures, five liver injuries, one splenic injury, and one renal injury, as well as transections of the external carotid-, vertebral-, axillosubclavian-, intercostal-, and lumbar arteries in one patient each (Table 1). All IVRs were transcatheter arterial embolizations (TAEs) for arterial bleeding. We performed selective embolization with coils and gelatin sponge to the internal iliac arteries (for pelvic fracture), the main branch of the hepatic artery (for liver injuries), the external carotid arteries (for multiple facial bone fracture), the intercostal arteries, and the lumber arteries. We also performed super selective embolization with microcoils to the other arteries under endovascular balloon occlusion of the aorta or a branch thereof.

The mean time from hospital arrival to the start of IVR was 56.3 ± 26.6 min, while that from the diagnosis to the start of IVR

Table 1
Injured organs and arteries.

Area	Injury Type	Number of injuries
Face & Neck	Le Fort I + II + III Type	1
	Transection of vertebral artery (V3)	1
Chest	Transection of axillosubclavian artery	1
	Chest wall injury	1
Abdomen	Liver	
	CT grade III	2
	CT grade IV	1
	CT grade V	2
	Spleen	
	CT grade IV	1
	Kidney	
	CT grade IV	1
Retroperito-neum and pelvis	Pelvis AO/OTA	
	Type A	1
	Type B	4
	Type C	5
	Transection of lumber artery	1

Please cite this article in press as: H. Otsuka, et al., Use of interventional radiology as initial hemorrhage control to improve outcomes for potentially lethal multiple blunt injuries, Injury (2017), https://doi.org/10.1016/j.injury.2017.11.038