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ORIGINAL ARTICLE

Improvement of outcomes in patients with pelvic fractures and hemodynamic instability after the establishment of a Korean regional trauma center

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Abstract

Purpose Despite using a multidisciplinary treatment approach, the mortality rate of patients with hemodynamic instability from severe pelvic fractures is still 40–60%. We evaluated the improvement of outcomes in this patient population after the establishment of a regional trauma center in Korea.

Methods We retrospectively reviewed the medical charts of 50 patients with hemodynamic instability due to pelvic fractures between March 2011 and November 2016. Patients were divided into two groups: the pre-trauma center (PTC) group ($n=23$) and trauma center (TC) group ($n=27$).

Results Sixteen (32.0%) patients died of exsanguination. Patients in the TC group had shorter trauma resuscitation room stay (101 vs 273 min, $p<0.001$) and underwent preperitoneal pelvic packing (PPP) more frequently (88.9 vs 8.7%, $p<0.001$) than those in the PTC group. During the TC period, emergent procedures such as PPP and pelvic angiography were performed more frequently (92.6 vs 39.1%, $p<0.001$). Although there was no statistical difference in the overall mortality rate between groups, patients in the TC group had less mortality due to hemorrhage (18.5 vs 47.8%, $p=0.027$). Logistic regression analysis demonstrated that initial systolic blood pressure and establishment of trauma center were independent protective factors of mortality from hemorrhage [odds ratio (OR) 0.957, 95% confidence interval (CI) 0.926–0.988, $p=0.007$; OR 0.134, 95% CI 0.028–0.633, $p=0.011$].

Conclusions Since the regional trauma center was established, emergent procedures such as pelvic angiography and PPP were performed more frequently, and mortality due to exsanguination was significantly decreased.

Keywords Pelvis · Hemorrhage · Trauma center · Preperitoneal pelvic packing · Damage control

Introduction

The preventable trauma-related mortality rate in Korea has gradually decreased from 50.4% in 1998, to 39.6% in 2004, and 32.6% in 2007 with the development of an emergency medicine medical center system [1]. However, the latest domestic preventable trauma-related mortality rate published in 2012 shows that it is now 35.2% [2]. In that study, the authors reported that trauma centers and teams that consisted of physicians dedicated to trauma were essential for better patient outcomes, and regional emergency medical centers had limitations to transport trauma patients and patient management proceeded by consultations. Based on these data, the government implemented the trauma center project, which sought to establish 17 regional trauma centers over the country by 2020 [3]. To date, 14 hospitals have been selected as regional trauma centers, and each received approximately 8 billion Korean Won of support to create or update the facilities, and pay for the annual salaries for trauma surgeons.

Although uncommon, treating patients with hemodynamic instability due to pelvic fracture is challenging and has several management modalities [4]. Pelvic

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angioembolization and external fixation, and the preperitoneal (extraperitoneal) pelvic packing (PPP) are the main techniques used to control bleeding in these patients, but the mortality rate is still greater than 30% [5–12]. The Wonju Severance Christian Hospital was selected as the regional trauma center of the Gangwon province in 2012 and opened in October 2014, and patients with pelvic fractures and shock have been managed by a trauma team using a consistent protocol. The aim of this study was to evaluate the improvement of outcomes in patients with pelvic fractures and hemodynamic instability after the establishment of this trauma center.

Methods

Patient selection

This study was approved by the institutional review board (IRB No: CR316111). Overall, 479 patients with pelvic fractures were admitted to a tertiary university hospital (Wonju Severance Christian Hospital, Wonju, Republic of Korea) between March 2011 and November 2016. Of these patients, patients with hemodynamic instability caused by severe pelvic fractures were enrolled in this study. Hemodynamic instability was defined as persistent hypotension (systolic blood pressure < 90 mmHg) despite 2 L crystalloid loading and transfusion of 2 units of packed red blood cells (RBCs) [11]. The following patients were excluded from the study. (1) Patients with AIS > 4 combined injuries of other area except from head injury and (2) patients whose main cause of hemorrhage was not a pelvic fracture but injury of another site.

Based on the date that the trauma center was established, patients admitted between March 2011 and September 2014 were included in the pre-trauma center (PTC) group, and those admitted between October 2014 to November 2016 were included the trauma center (TC) group (Fig. 1). We retrospectively reviewed electronic medical data including patient demographics, mechanism of injury, initial hemodynamic status and laboratory findings for 4 h from admission, associated injuries, blood transfusion requirement, time to admission, time from admission to emergent surgery or intervention, time of trauma resuscitation room stay, pelvic fracture pattern (Young–Burgess classification), overall mortality, and hemorrhage-induced mortality.

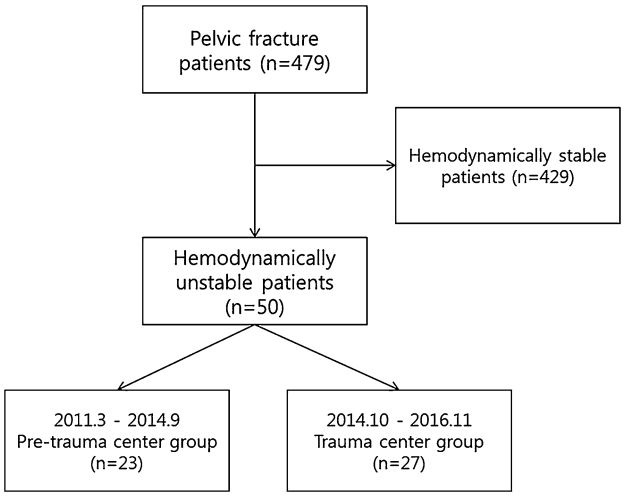

Fig. 1 CONSORT diagram

Management of patients with pelvic fractures and hemodynamic instability

During the PTC period, trauma patients were initially sent to the trauma resuscitation room, and managed by a trauma team consisting of general surgeons, a cardio-thoracic surgeon, and emergency physicians. When hypotension (systolic blood pressure < 90 mmHg) persisted despite resuscitation with 2L crystalloid and two units of packed RBCs, a massive transfusion protocol was initiated and extended Focused Assessment with Sonography for Trauma (eFAST) examination and trauma series X-rays [cervical spine lateral, chest anterior–posterior (AP), and pelvis AP X-ray] were performed. Pelvic angiography was performed after emergent thoracotomy or laparotomy if fluid collection was detected in the thoracic or abdominal cavity by eFAST and severe pelvic fracture observed on pelvis AP X-ray imaging. Emergent pelvic angiography was performed at first to control bleeding from the branches of the internal iliac artery in cases of hemodynamic instability combined with severe pelvic fracture based on pelvis AP X-ray imaging, but in cases without indication of fluid collection in the thoraco-abdominal cavity on eFAST. PPP began to be used in May 2014 to control severe pelvic hemorrhage due to severe pelvic fractures [11]. The management protocol was updated to include PPP for patients with pelvic fracture in May 2014, based on the protocol of the Rocky Mountain Regional Trauma Center at Denver Health [13]. Patients underwent emergent pelvic external fixation at the discretion of the orthopedic surgeon. Pelvic binder was applied in the trauma resuscitation room for patients with complete disruption of pelvic rim except lateral compression type to reduce the pelvic volume during both periods.

PPP was performed by trauma surgeons in patients with pelvic fractures who were hemodynamically unstable. The orthopedic surgeon then decided whether pelvic external fixation was necessary. Resuscitation and correction of the coagulopathy were conducted in the trauma intensive care unit (TICU) until patients stabilized; packed surgical pads were subsequently removed within 48 h [11, 14].

Statistical analysis

Continuous variables were expressed as mean ± standard deviation or median (range). Differences between the two groups were compared using the Chi-square, student *t*, Fisher's exact, and Mann–Whitney *U* tests. Logistic regression analysis was used to evaluate risk factors associated with hemorrhagic mortality, and results expressed as odds ratios (ORs) with 95% confidence interval (CI). p values < 0.05 were considered statistically significant. All calculations were performed using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA).

Results

Clinical characteristics of patients with hemodynamic instability due to pelvic fracture

Altogether, 50 consecutive patients with hemodynamic instability due to pelvic fracture were enrolled during the study period (69 months). Twenty-eight (56%) patients were men and the mean age was 59.6 ± 18.6 years. The mean injury severity score was 39.6 ± 9.0 and 43 (86%) patients had combined injuries. Thirty percent of patients also had head injuries, 54% chest injuries, 38% abdominal injury, and 6% facial injuries. The most common mechanism of injury was auto-pedestrian accident ($n = 22$, 44%), followed by motor vehicle collision, fall, crushing, and motor cycle collision. The mean admission systolic blood pressure (SBP) was 83.3 ± 29.3 mmHg, hemoglobin level was 10.3 ± 2.7 g/dL, and serum lactate level was 5.09 ± 3.13 mmol/L. Pelvic fracture classifications were lateral compression (LC) III ($n = 19$, 38%), LC II (12, 24%), anterior posterior compression (APC) II (10, 20%), vertical shear (9, 18%), LC I (4, 8%), and APC III (1, 2.0%). Three patients had open pelvic fractures. The mean time from injury to admission was 117.5 ± 94 min. The median time of trauma resuscitation room stay and median time from admission to emergent procedure were 146.5 (range, 34–1215) and 105.5 (26–555) min, respectively. Twenty-six (52%) patients underwent PPP and pelvic external fixation was performed emergently in seven patients (14.0%). Among 21 (42.0%) patients who underwent emergent pelvic angiography, 10 (47.6%) needed arterial embolization. Four patients were treated with PPP and angioembolization concurrently in a hybrid operating room. Except for one patient who was first admitted to TICU, the other three were sent to the hybrid operation room, which took 35, 43, and 97 min respectively. After a median of seven units of packed RBCs (range 2–53) was transfused during the first 4 h after admission, patients required two more units of packed RBCs (range 0–24) during the next 12 h. Excluding eight patients who died in the trauma resuscitation room, median durations of intensive care unit stay and mechanical ventilation were 7.5 (range 1–157) and 4.5 (0–157) days. Twenty-three (46%) patients died, including 16 (32%) who died from acute hemorrhage (Table 1).

Table 1 Patient characteristics

Variable	$N = 50$ (%)
Gender (men)	28 (56.0)
Age (year)	59.6 ± 18.6
Injury severity score	39.6 ± 9.0
Injury mechanism	
Auto-pedestrian accident	22 (44.0)
Motor vehicle collision	13 (26.0)
Fall	11 (22.0)
Crush	3 (6.0)
Motorcycle	1 (2.0)
Combined injury	43 (86.0)
Head	15 (30.0)
Face	3 (6.0)
Chest	27 (54.0)
Abdomen	19 (38.0)
Initial SBP (mmHg)	83.3 ± 29.3
Initial Hb (g/dL)	10.3 ± 2.7
Initial lactate (mmol/L)	5.09 ± 3.13
B&Y classification	
APC II/APC III	5 (10.0)/1 (2.0)
LC I/LC II/LC III	4 (8.0)/12 (24.0)/19 (38.0)
Vertical shear	9 (18.0)
Open fracture	3 (6.0)
Transfer from another hospital	27 (54.0)
Time from injury to admission (min)	117.5 ± 94.0
Trauma resuscitation room stay (min)	146.5 (34–1215)
Time to emergent procedure (min)	105.5 (26–555)
Preperitoneal pelvic packing	26 (52.0)
Pelvic external fixation	7 (14.0)
Angiography/embolization	21 (42.0)/10
Emergent laparotomy	9 (18.0)
Packed RBC transfusion for 4 h (unit)	7 (2–53)
ICU stay (day, 42 patients)	7.5 (1–157)
Mortality	23 (46.0)
Mortality *d/t* exsanguination	16 (32.0)
Duration of mechanical ventilation (day, 42 patients)	4.5 (0–157)
Hospital day	27 (1–157)

SBP systolic blood pressure, *APC* anterior–posterior compression, *LC* lateral compression, *RBC* red blood cell, *ICU* intensive care unit

Pre-trauma vs post-trauma center period group

No significant differences were observed between groups including sex ($p=0.615$), age ($p=0.164$), injury severity score ($p=0.334$), mechanism of injury ($p=0.968$), fracture type ($p=0.462$), or occurrence of associated injury ($p=0.225$). No significant differences were seen in the initial and worst hemodynamic status between groups, including initial SBP ($p=0.664$), diastolic blood pressure (DBP) ($p=0.901$), initial hemoglobin ($p=0.362$), initial lactate ($p=0.953$), or worst lactate after admission ($p=0.526$). Mean time from injury to admission ($p=0.104$) and from admission to emergency procedure ($p=0.234$) was not significantly different between groups. Patients in the TC group, however, stayed in the trauma resuscitation room for a shorter period of time than those in the PTC group [101 min (range 34–252) vs 273 min (64–1215); $p<0.001$]. Emergent procedures were performed more frequently in the TC period than in the PTC period [$n=25$ (92.6%) vs $n=9$ (39.1%); $p<0.001$]. In addition, no differences were observed in the rate of emergent pelvic external fixation [1 (4.3%) vs 6 (22.2%); $p=0.103$] or pelvic angiography [10 (43.5%) vs 11 (40.7%); $p=0.845$] between groups. Mortality rates were not significantly different between groups either: 52.2% in the PTC group vs 40.7% in the TC group ($p=0.419$). However, the mortality rate due to hemorrhage was significantly lower in the TC group than in the PTC group (18.5 vs 47.8%, $p=0.027$) (Table 2).

Risk factors associated with mortality due to hemorrhage

Sixteen patients who died from hemorrhage had more open fractures (18.8 vs 0%, $p=0.029$), lower initial SBP (67.3 ± 32.6 vs 90.8 ± 24.7 mmHg, $p=0.007$) and DBP (36.5 ± 18.4 vs 51.4 ± 16.9 mmHg, $p=0.007$),

Table 2 Pre- vs post-trauma center period

	Before trauma center ($n=23$) (%)	After trauma center ($n=27$) (%)	
Gender (men)	12 (52.2)	16 (59.3)	0.615
Age (years)	55.5 ± 21.8	63.2 ± 14.9	0.164
Injury severity score	38.2 ± 9.0	40.7 ± 9.0	0.334
Injury mechanism			0.968[a]
Auto-pedestrian accident	11 (47.8)	11 (40.7)	
Motor vehicle collision	5 (21.7)	8 (29.6)	
Fall	5 (21.7)	6 (22.2)	
Crush	1 (4.3)	2 (7.4)	
Motorcycle	1 (4.3)	0 (0)	
Open fracture	2 (8.7)	1 (3.7)	0.588[a]
Combined injury	18 (78.3)	25 (92.6)	0.225[a]
Initial SBP (mmHg)	85.3 ± 21.5	81.6 ± 34.9	0.664
Initial Hb (g/dL)	10.6 ± 3.1	9.9 ± 2.3	0.362
Initial lactate (mmol/L)	5.06 ± 3.41	5.11 ± 2.93	0.953
Transfer from another hospital	12 (52.2)	15 (55.6)	0.811
Time from injury to admission (min)	94.9 ± 65.1	136.8 ± 110.5	0.104
Trauma resuscitation room stay (min)	273 (64–1215)	101 (34–252)	**<0.001**
Time to emergent procedure (min)	178.0 ± 103.6	126.8 ± 110.2	0.234
Preperitoneal pelvic packing	2 (8.7)	24 (88.9)	**<0.001**
External fixation	1 (4.3)	6 (22.2)	0.103[a]
OR-IF	5 (21.7)	9 (34.6)	0.319
Pelvic angiography	10 (43.5)	11 (40.7)	0.845
Emergent procedure	9 (39.1)	25 (92.6)	**<0.001**
ICU stay (42 patients)	6.5 (1–157)	11 (1–39)	0.774
Mortality	12 (52.2)	11 (40.7)	0.419
Mortality due to hemorrhage	11 (47.8)	5 (18.5)	**0.027**

Bold values are statistically significant

SBP systolic blood pressure, *Hb* hemoglobin, *OR-IF* open reduction and internal fixation, *ICU* intensive care unit

[a]Result of Fisher's exact test

and higher initial serum lactate level (6.36 ± 3.66 vs 4.48 ± 2.69 mmol/L, $p = 0.046$) than those who survived after hemorrhage. In particular, survivors underwent PPP [$n = 20$ (60.6%) vs $n = 5$ (31.2%); $p = 0.044$] and were treated while being part of the regional trauma center system [$n = 22$ (64.7%) vs $n = 5$ (31.3%); $p = 0.027$] more frequently than those who died (Table 3). Logistic regression model using initial SBP, initial serum lactate, establishment of the trauma center, and PPP showed that initial SBP (OR 0.962, 95% CI 0.934–0.991, $p = 0.010$) and establishment of trauma center (OR 0.134, 95% CI 0.028–0.633, $p = 0.011$) were independently correlated with lower risk of hemorrhagic mortality (Table 4).

Table 4 Multivariate analysis of factors associated with mortality due to hemorrhage

Variables	Risk factors for mortality *d/t* hemorrhage	
	OR (95% CI)	*p* value
Initial systolic blood pressure	0.957 (0.926–0.988)	**0.007**
Initial serum lactate	1.169 (0.920–1.485)	0.210
Establishment of trauma center	0.134 (0.028–0.633)	**0.011**
Preperitoneal pelvic packing	0.663 (0.066–6.696)	0.727

Bold values are statistically significant

OR odds ratio, *CI* confidence interval

Discussion

The regional trauma center building that was added to the regional emergency medical center as part of the Korean government project includes two beds in the trauma resuscitation rooms, 20 beds in the TICU, 40 beds in the general trauma ward, and two operation rooms, including one hybrid operation room. The team dedicated to trauma comprises six general surgeons, two cardio-thoracic surgeons, three neurosurgeons, two orthopedic surgeons, and one emergency medicine physician. Trauma team members on duty initiate patient management within 10 min from the time the trauma team call are activated, per the trauma team call criteria. Our

Table 3 Comparison between survivors and non-survivors

	Survivor ($n = 34$) (%)	Mortality *d/t* hemorrhage ($n = 16$) (%)	
Men	19 (55.9)	9 (56.2)	0.981
Age (years)	59.8 ± 15.2	59.3 ± 24.9	0.933
Injury severity score	38.7 ± 7.2	41.3 ± 12.0	0.435
Injury mechanism			0.424**
Fracture type			0.096[a]
Open fracture	0	3 (18.8)	**0.029**[a]
Combined injury	31 (91.2)	12 (75.0)	0.190[a]
Initial SBP (mmHg)	90.8 ± 24.7	67.3 ± 32.6	**0.007**
Initial hemoglobin (g/dL)	10.3 ± 2.3	10.1 ± 3.5	0.823
Initial lactate (mmol/L)	4.48 ± 2.69	6.36 ± 3.66	**0.046**
RBC transfusion for 4 h (unit)	7 (2–28)	11 (4–53)	0.037
Transfer from another hospital	18 (52.9)	9 (56.3)	0.827
Time from injury to admission (min)	101.5 (18–291)	78 (8–499)	0.343
Trauma resuscitation room stay (min)	143.5 (35–1215)	174 (34–640)	0.563
Time to emergent procedure (min)	137.5 ± 112.2	147.4 ± 107.6	0.813
Preperitoneal pelvic packing	20 (60.6)	5 (31.2)	**0.044**
External fixation	6 (18.2)	1 (6.2)	0.406[a]
OR-IF	14 (42.4)	0	0.002[a]
Angiography	14 (41.2)	7 (43.8)	0.863
Emergent procedure	24 (70.6)	10 (62.5)	0.567
Establishment of trauma center	22 (64.7)	5 (31.3)	**0.027**
ICU stay (days) (42 patients)	11 (2–157)	1 (1–6)	0.101

Bold values are statistically significant

SBP systolic blood pressure, *DBP* diastolic blood pressure, *RBC* red blood cell, *OR-IF* open reduction and internal fixation, *OR* operation room, *ICU* intensive care unit

**Result of linear by linear association

[a]Results of Fisher's exact test

trauma center has several time-sensitive goals: (1) patient admission is determined within 30 min of presentation and (2) definitive treatment is performed within 1 h of admission. In our study, we found that patients with pelvic fractures and shock in the TC group underwent emergent procedures more frequently ($p < 0.01$) and stayed in the trauma resuscitation room for a shorter period of time ($p < 0.01$) than those in the PTC group. These data potentially suggest that the general surgeons and orthopedic surgeons of the trauma team were involved early enough in patient management, because they did not need patient treatment consultations. Furthermore, they performed aggressive, damage control procedures, including PPP or pelvic external fixation, to stop pelvic hemorrhage. Emergent surgeries and admissions were not delayed because of preparations of the operating room or intensive care unit for trauma patient.

Before the trauma center opened, hemodynamically unstable patients due to pelvic fractures were managed by orthopedic surgeons or general surgeons. In many cases, the two departments had conflicting attitudes about admission and patient management, potentially because orthopedic surgeons were not accustomed to shock management, while general surgeons were not used to fracture management. This caused delays when making decisions in patients with hemodynamic instability and aggravation of coagulopathy. In one study, Biffl et al. reported that the application of a multidisciplinary clinical pathway using joint decision making between trauma surgeons and orthopedic trauma surgeon resulted in improved survival rate in these patients [15]. We also showed that the establishment of trauma center was an independent factor associated with reduction of hemorrhage-induced mortality (OR 0.134, CI 0.028–0.633, $p = 0.011$). This is probably due to the combination of rapid decision making by the multidisciplinary team approach and adequate facilities for the treatment of trauma patients after the establishment of the trauma center.

PPP played an important role in managing patients with hemodynamic instability due to pelvic fractures because of its quick and simple application and hemostatic effect. Because hemorrhage due to pelvic fracture predominantly originates from the bone and vein, while arterial bleeding occurs in only approximately 15% of cases, pelvic angiography is often useless and time consuming [16, 17]. In their study, Burlew et al. reported excellent clinical results using a combination of PPP and external fixation prior to pelvic angiography in 128 patients with pelvic fractures and shock: 27 (21%) patients died and only three (2.3%) died from exsanguination [18]. Several recent studies have reported an equivalent or a reduction in mortality among patients who underwent PPP, compared with angioembolization [19–21]. However, our data showed that PPP significantly reduced the risk for mortality from hemorrhage in the univariate analysis ($p = 0.044$), but not in the multivariate analysis ($p = 0.727$). More experiences may be needed to confirm the effectiveness of PPP itself in reducing hemorrhagic death.

Although patients stayed a shorter period of time in the trauma resuscitation room after the trauma center was established, the overall mortality we observed in this study still remained high, compared with data from the 2016 American Association for the Surgery of Trauma multicenter study (40.7 vs 32%) [4]. We believe that this is due to our long 137-min mean time from injury to trauma center admission. This delay in admission may be due to several factors. First, the province where our trauma center is located has many mountainous areas, which makes fast transport from the accident point to the trauma center or inter-hospital transport difficult. Second, because this trauma center is still new, we have not yet systematized the transfers and referrals of trauma patients. In particular, smaller hospitals in our province do not yet have the facilities or personnel for trauma patient care. There is also no control tower to transfer and allocate trauma patients between these hospitals and trauma centers. Third, the number of transfers from small hospitals in the area to our trauma center increased after it was established, which contribute to a delay from the accident to arrival at the trauma center. For these reasons, it will be necessary to systematize the transfer of patients between the trauma center and surrounding hospitals once the regional trauma centers are finalized, and additional efforts should be made to support trauma education, facilities, and manpower for these hospitals.

We acknowledge several limitations in this study. The main limitations are its retrospective design and sample size, which is too small to confirm the changes in management of patients with pelvic fractures and shock. In addition, because this was a single center study, it may be difficult to representatively assess the impact of the Korean trauma center project on these patients. Despite these limitations, this study is meaningful, because it provides information on the positive changes that have occurred since the establishment of our trauma center in patients with hemodynamically unstable pelvic fractures. It also shows many implications for complementing the Korean trauma system in the future.

Conclusions

Since our regional trauma center was established, emergent procedures for patients with pelvic fracture patients and hemodynamic instability, including pelvic angiography and PPP, were performed more frequently and actively, and mortality from exsanguination was significantly decreased. However, we found that transferring patients from the accident site to the trauma center and inter-hospital transfers were still delayed. Additional education and support is needed for the treatment of trauma patients in the surrounding hospitals,

as well as the establishment of a control tower, to manage the transfer of patients to our trauma center.

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Compliance with ethical standards

Conflict of interest There are no potential conflicts of interest for each of the authors.

Ethics statement The present study protocol was reviewed and approved by the institutional review board of Wonju Severance Christian Hospital (Reg. No. CR316111). Informed consent was exempted, because it was a retrospective study.

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