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# Multi-lumen catheter insertion during trauma resuscitation: assessing clinical outcomes and complications

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## Abstract

# Background

Massive transfusion is essential in trauma resuscitation; however, reliable, high-flow vascular access remains challenging. The multi-lumen access catheter (MAC) was designed as a trauma-dedicated central line enabling rapid transfusion. However, evidence on the optimal MAC insertion site is limited. This study compared clinical outcomes and complications of subclavian vein (SCV) vs. femoral vein (FV) MAC placement in severely injured patients.

# Methods

This retrospective study was conducted at a single Level I trauma center between January 2019 and December 2022. Adult patients (≥ 18 years) with blunt trauma, Injury Severity Score ≥ 15, MAC placement during initial trauma bay resuscitation were included. All patients fulfilled criteria for massive transfusion. Primary outcomes included 30-day mortality and insertion site-related complications, categorized as FV or SCV. Mortality predictors were evaluated using multivariable logistic regression. Subgroup analysis examined patients with severe abdominal or pelvic injuries (Abbreviated Injury Scale [AIS] ≥ 3) to evaluate outcomes by insertion above or below the diaphragm.

# Results

In total, 412 patients were analyzed (SCV 224, 54.4%; FV 188, 45.6%). Patients in the FV group had lower Glasgow Coma Scale (GCS) and higher lactate levels, whereas severe pelvic injuries were more frequent in the SCV group. Procedural complications differed by site: failed catheterization was more frequent with SCV (9.0% vs. 2.1%), alongside pneumothorax (5.7%) and malposition (3.3%). Thromboembolic complications showed opposite patterns: deep vein thrombosis was more common in the FV group (18.1% vs. 5.4%), whereas pulmonary thromboembolism was higher in the SCV group (4.0% vs. 0.5%). No central line–associated bloodstream infection was observed. Thirty-day mortality was higher in the FV group (25% vs. 15.2%); however, insertion site was not an independent mortality predictor. Mortality predictors included age, low mean arterial pressure, low GCS, elevated lactate, and severe head/neck, chest, or extremity injuries. In the abdominal/pelvic AIS ≥ 3 subgroup, outcomes did not differ by insertion site.

# Conclusion

MAC insertion during trauma resuscitation was feasible and effective, with distinct complication profiles between SCV and FV access. Mortality was determined by physiology and injury severity, not catheter

site. Vascular access decisions should be individualized, balancing technical feasibility, injury pattern, and complication risk.

## Background

Intravascular access is fundamental for resuscitating trauma patients with hemorrhagic shock. Advanced Trauma Life Support (ATLS) guidelines, recommend prompt vascular access via insertion of two large-bore peripheral intravenous (PIV) catheters (≥ 16 gauge) (1). However, peripheral venous access may not be feasible in hemorrhagic shock with vascular collapse or in patients with limited or small-caliber veins, making catheter placement difficult (2, 3).

Consequently, the need for trauma-dedicated central venous catheters (CVCs) that are large-caliber and short-length to facilitate rapid blood product infusion during trauma resuscitation remains a topic of debate (4). The 9-Fr multi-lumen access catheter (MAC; Arrow, Teleflex, PA, USA) delivers blood products faster than an 18-gauge peripheral catheter (5) (Fig. 1). Despite these advantages, large-bore CVC insertion carries catheter-related complications, and evidence on the optimal insertion site for MAC during trauma resuscitation, particularly its impact on patient outcomes, remains limited.

During trauma resuscitation, MAC insertion site selection is proposed to depend on the injury site relative to the vena cava, with catheter placement above or below the diaphragm. However, these recommendations remain largely expert opinion with limited supporting evidence (6, 7). Furthermore, in polytrauma, MAC insertion site selection may be influenced by multiple factors, including the presence of extremity injuries and physician's experience. This study investigates the effect of MAC insertion site on mortality and complication rates among patients with blunt trauma.

## Materials and methods

# Patients and setting

This retrospective study included trauma patients treated at a single Level 1 trauma center between January 2019 and December 2022. Our center is a a tertiary academic hospital serving a catchment population of 1.3 million and admits approximately 4,000 trauma patients annually per the Korean Trauma Data Bank.The trauma center is an independent facility with 100 trauma care units, including two trauma bays, 40 trauma intensive care unit (ICU) beds, and three trauma operating theatres.

Adult patients (≥ 18 years) with blunt trauma who received MAC placement in the trauma bay during initial resuscitation were included. Exclusion criteria were: patients who did not meet massive transfusion criteria (> 10 units of red blood cells [RBCs] within 24 h, > 4 units within 4 h, or activation of the massive transfusion protocol), an Injury Severity Score (ISS) < 15, penetrating injuries, internal jugular vein MAC placement, death due to brain injury, or cardiopulmonary resuscitation upon arrival. At our institution, MACs are preferentially inserted into the subclavian or femoral vein using anatomical

landmarks. Internal jugular access was excluded because cervical immobilization during trauma resuscitation in blunt trauma limits accessibility before cervical spine clearance.

## Treatment protocol

At our institution, a trauma-dedicated central line—the 9-Fr Multi-lumen Access Catheter (MAC, Arrow, Teleflex, PA, USA)—is routinely available. Since 2015, our institution implemented the massive transfusion protocol (MTP) to improve effectiveness of resuscitation approaches (Additional File 1). MTP is indicated for severely injured patients with hemodynamic instability and evidence of active bleeding in the thorax, abdomen, pelvis, or extremities. The protocol requires vascular access via two large-bore (≥ 18 G) peripheral catheters in the upper extremities or, when necessary, MAC placement.

The MAC insertion site was determined by the trauma team leader, in a multidisciplinary trauma team comprising trauma surgeons, cardiothoracic surgeons, and emergency medicine specialists, based on injury pattern and risk–benefit considerations. Trauma specialist inserted catheters in the trauma bay using traditional anatomical landmark-guided puncture of the subclavian or femoral vein under emergency conditions. MACs were routinely removed within 48 h according to Centers for Disease Control and Prevention guidelines owing to the emergent nature of the setting (8). Ultrasound, though always available, was not systematically used during trauma resuscitation because of urgent situations. Most blood products were delivered through a MAC catheter connected to the fluid management system (FMS 2000, The Belmont Rapid Infuser).

## Data collection

Data were retrospectively extracted from electronic medical records (EMRs) and the institutional trauma registry. Collected variables included patient demographics, comorbidities, and injury profiles such as mechanism of injury, ISS, and presence of severe head, neck, face, chest, abdomen, pelvis, or extremity injuries, defined as an Abbreviated Injury Scale (AIS) score of ≥ 3. Physiologic parameters on arrival, including mean arterial pressure (MAP), presence of shock (MAP < 65 mmHg), and Glasgow Coma Scale (GCS) score, were also recorded. Transfusion variables included the type and volume of blood products administered within the first 4 h and 24 h after arrival. Catheter-related variables included insertion site and procedure-related complications such as arterial puncture, malposition, venous thrombosis, pneumothorax, or hemorrhage requiring intervention. All complications were confirmed via EMRs or relevant imaging performed during admission. The occurrence of central line–associated bloodstream infection (CLABSI) related to MAC insertion was additionally assessed.

Patients were categorized into two groups according to the final MAC insertion site: the subclavian vein group (SCV group) and the femoral vein group (FV group). To assess procedure-related complications, procedure-based classification was performed according to the site of attempted MAC insertion. In

addition, a subgroup analysis was performed in patients with severe abdominal or pelvic injuries (AIS ≥ 3) to evaluate whether MAC insertion above or below the diaphragm influenced patient outcomes.

## Statistical analyses

Normality was tested using the Shapiro–Wilk test. For non-normally distributed data, the Mann–Whitney U test was used. If data were normally distributed, a two-sample t-test was used. Continuous variables are presented as median with interquartile range (IQR). Categorical variables were compared using the chi-square or Fisher's exact tests, as appropriate, and expressed as proportions. Variables with $p < 0.20$ in the univariate analysis were entered into a multivariable logistic regression analysis using stepwise selection to identify mortality risk factors after trauma resuscitation. Statistical analyses were conducted using SPSS ver. 29 (SPSS, Chicago, IL, USA). A $p$-value < 0.05 was considered statistically significant.

## Ethics statement

This study was approved by the Institutional Review Board of Ajou University Hospital (IRB No. AJOUIRB-DB-2025-218) and the requirement for informed consent was waived due to the retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations, including the Declaration of Helsinki and institutional policies for research involving human subjects. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (9).

## Results

# Patients

During the study period, 749 patients underwent MAC placement during trauma resuscitation for massive transfusion. After applying exclusion criteria, 412 patients were included in the final analysis: 224 patients (54.4%) in the SCV group and 188 (45.6%) in the FV group (Fig. 2). These patients accounted for 423 MAC insertions, as some underwent more than one procedure. Additionally, IO access was performed in 27 of 412 patients (6.6%) when large-bore peripheral IV access could not be established.

Baseline patient characteristics are summarized in Table 1. All patients experienced blunt trauma, and the mechanism of injury, and ISS were not significantly different between two groups. Both groups were generally comparable in terms of age and sex. However, patients in the FV group presented with lower GCS (12 (IQR) [5, 14] vs. 12.5 [7, 14], $p = 0.039$) and higher lactate levels (6.1 mmol/L [4.3, 9.3] vs. 5.3mmol/L [2.7, 7.9], $p = 0.011$). A significantly larger proportion of patients with severe pelvic injury (pelvis AIS ≥ 3) were observed in the SCV group (44.6% vs. 28.2%, $p = 0.001$). (Table 1) Clinical outcomes

for the overall cohort are presented in Table 2. Transfusion volume and hemorrhagic control procedures were similar between the two groups. Deep vein thrombosis (DVT) was more common in the FV group (18.1% vs. 5.4%, $p < 0.001$). Pulmonary thromboembolism (PTE) prevalence was significantly higher in the SCV group (4.0% vs. 0.5%, $p = 0.025$). Thirty-day mortality was higher in the FV group (25% vs. 15.2%, $p = 0.012$) (Table 2).

Table 1
Demographic and injury characteristics of study population

| Variables | SCV group (n = 224) | FV group (n = 188) | *p-value* |
|---|---|---|---|
| Age, median (IQR) (years) | 52.5 (33–63) | 52 (37–64) | *0.611* |
| Sex, n (%) | | | *0.437* |
| Male | 173 (77.2) | 139 (73.9) | |
| Female | 51 (22.8) | 49 (26.1) | |
| Mechanism of injury, n (%) | | | *0.489* |
| Free fall | 74 (33.0) | 51 (27.1) | |
| Motor vehicle accident | 51 (22.8) | 36 (19.1) | |
| Motorcycle accident | 33 (14.7) | 35 (18.6) | |
| Bicycle/Pedestrian | 39 (17.4) | 48 (25.6) | |
| Machinery | 4 (1.8) | 4 (2.1) | |
| Struck | 18 (8.0) | 7 (3.7) | |
| Other blunt injury | 5 (2.2) | 7 (3.7) | |
| Arrived from, n (%) | | | *0.714* |
| Scene | 184 (82.1) | 157 (83.5) | |
| Outside hospital | 40 (17.9) | 31 (16.5) | |
| Initial SBP, n (%) | | | *0.187* |
| < 90 mmHg | 73 (32.6) | 73 (38.8) | |
| ≥ 90mmHg | 151 (67.4) | 115 (61.2) | |
| Initial SBP, mean (IQR) (mmHg) | 105 (81.3–130) | 96 (80–123) | *0.141* |
| Initial MAP, mean (IQR) (mmHg) | 82 (63.4–107.5) | 74.7 (60–95) | *0.064* |
| Initial GCS, median (IQR) | 12.5 (7–14) | 12 (5–14) | *0.039** |
| Initial lactic acid, median (IQR) (mmol/L), | 5.3 (2.7–7.9) | 6.1 (4.3–9.3) | *0.011** |
| Known associated injuries, AIS ≥ 3, n (%) | | | |
| Head and neck | 38 (17.0) | 42 (22.3) | *0.169* |
| Face | 3 (1.3) | 2 (2.3) | *1.000* |
| Chest | 58 (25.9) | 60 (31.9) | *0.178* |

| Variables | SCV group (n = 224) | FV group (n = 188) | *p-value* |
|---|---|---|---|
| Abdomen | 113 (50.4) | 102 (47.4) | *0.441* |
| Pelvis | 100 (44.6) | 53 (28.2) | *0.001** |
| Extremity | 11 (4.9) | 11 (5.9) | *0.672* |
| ISS, median (IQR) | 38 (29–43) | 37 (27–45) | *0.759* |
| Underlying diseases, n (%) | 110 (49.1) | 80 (40.6) | *0.184* |

*$p < 0.05$

SCV, subclavian vein; FV, femoral vein; IQR, Interquartile range; SBP, systolic blood pressure; MAP, mean arterial pressure; GCS, Glasgow coma scale; AIS, abbreviated injury scale; ISS, injury severity scale.

Table 2
Patient's outcomes and complications related to trauma

| Variables | SCV group (n = 224) | FV group (n = 188) | *p-value* |
|---|---|---|---|
| RBC transfusion, median (IQR) (units) | | | |
| Within 4 h | 10 (6–13.8) | 9 (6–14) | *0.849* |
| Within 24 h | 10.5 (6–16) | 11 (8–18) | *0.447* |
| FFP transfusion, median (IQR) (units) | | | |
| Within 4 h | 8 (6–12) | 8 (6–16) | *0.278* |
| Within 24 h | 10 (8–16) | 12 (8–20) | *0.425* |
| Procedure for hemorrhagic control, n (%) | | | *0.704* |
| Operation | 83 (37.1) | 79 (42) | |
| Intervention | 59 (26.3) | 42 (22.3) | |
| Both | 41 (18.3) | 32 (17.0) | |
| Conservative care | 41 (18.3) | 35 (18.6) | |
| Complications related to trauma, n (%) | | | |
| VTE, n (%) | 16 (7.1) | 34 (18.1) | *0.001** |
| DVT, n (%) | 12 (5.4) | 34 (18.1) | *< 0.001** |
| PTE, n (%) | 9 (4.0) | 1 (0.5) | *0.025** |
| CLABSI, n (%) | 0 (0) | 0 (0) | *N/A* |
| ICU LOS, median (IQR), (d) | 8.5 (4–18) | 8 (3.5–17.5) | *0.959* |
| Ventilator days, median (IQR), (d) | 4 (2–11.5) | 4 (1–11) | *0.574* |
| Hospital LOS, median (IQR), (d) | 31.5 (17–48) | 26 (12.5–45) | *0.079* |
| 30-day mortality, n (%) | 34 (15.2) | 47 (25.0) | *0.012** |
| *$p < 0.05$ | | | |
| SCV, subclavian vein; FV, femoral vein; VTE, venous thromboembolism; DVT, deep vein thrombosis; PTE, pulmonary thromboembolism; CLABSI, central line-associated bloodstream infection; ICU, intensive care unit; LOS, length of stay; IQR, interquartile range. | | | |

[Insert Table 1 here]

[Insert Table 2 here]

# Procedural complications

Procedural complications related to MAC placement are presented in Table 3. Failed catheterization was more frequent with SCV placement (9.0% vs. 2.1%, $p = 0.003$). SCV insertion was associated with mechanical complications such as pneumothorax (5.7%) and catheter malposition (3.3%). Hemorrhagic events requiring treatment occurred in two cases (0.8%) in the SCV group and in none in the FV group. One patient developed a progressive mediastinal hematoma requiring additional transfusion. Another patient with persistent shock and diaphragmatic bulging after emergent nephrectomy required subsequent thoracotomy, which revealed MAC-induced mediastinal vessel injury; the patient did not survive. Among “other” complications in the SCV group, two cases of catheter kinking rendered the line unusable. In one case the catheter penetrated the SCV and required removal via interventional radiology. In the FV group, two cases of arterial placement were identified; one was managed via catheter removal during angiographic intervention, and the other via catheter removal with concomitant arterioplasty during abdominal surgery.

Table 3

Complications per vascular access site[]

| **Variables** | **Subclavian v. (n = 245)** | **Femoral v. (n = 191)** | ***p-value*** |
|---|---|---|---|
| Failed catheterization, n (%) | 22 (9.0) | 4 (2.1) | *0.003* |
| Complications, n (%) | | | *< 0.001* |
| Pneumothorax | 14 (5.7) | 0 (0) | |
| Arterial placement, | 1 (0.4) | 2 (1.0) | |
| Malposition | 8 (3.3) | 1 (0.5) | |
| Hemorrhage requiring treatment | 2 (0.8) | 0 (0) | |
| Unable to cannulate | 12 (4.9) | 1 (0.5) | |
| Other | 3 (1.2) | 3 (1.6) | |
| None, n (%) | 205 (83.7) | 151 (79.1) | |

[]Total of 432 MAC insertions in 412 patients

[Insert Table 3 here]

# Subgroup analysis: patients with severe abdominal or pelvic injury (AIS ≥ 3)

A subgroup analysis was conducted in patients with AIS ≥ 3 in the abdomen or pelvis. Baseline characteristics of this subgroup are demonstrated in Table 4. Patients in the SCV group had a higher proportion of free fall injuries than those in the FV group. The FV group in this cohort had lower GCS (12 [6, 14] vs. 13 [7, 14], $p = 0.039$) and higher lactate levels (6.4mmol/L [4.5, 10.0] vs. 5.5mmol/L [3.9, 7.9], $p = 0.016$) than the SCV group (Table 4). Clinical outcomes for this subgroup are summarized in Table 5. Transfusion volume and hemorrhagic control procedures did not significantly differ between the two groups. ICU stay, hospital stay, and 30-day mortality did not significantly differ between two groups (Table 5). Notably, in the FV group, only four patients required additional intraoperative insertion of an internal jugular MAC by the anesthesiologist after confirmed inferior vena cava (IVC) injury in the operative field.

Table 4
Demographic and injury characteristics of severe abdomen or pelvis trauma patients (AIS ≥ 3)

| **Variables** | **SCV group (n = 168)** | **FV group (n = 129)** | ***p-value*** |
|---|---|---|---|
| Age, median (IQR) (years) | 50 (33, 62.8) | 48 (34, 62) | *0.764* |
| Sex, n (%) | | | *0.495* |
| Male | 127 (75.6) | 41 (24.4) | |
| Female | 93 (72.1) | 36 (27.9) | |
| Mechanism of injury, n (%) | | | *0.044** |
| Free fall | 63 (37.5) | 34 (26.4) | |
| Motor vehicle accident | 31(18.5) | 23 (17.8) | |
| Motorcycle accident | 22 (13.1) | 26 (20.2) | |
| Bicycle/Pedestrian | 31 (18.5) | 36 (27.9) | |
| Machinery | 2 (1.2) | 1 (0.8) | |
| Struck | 15 (8.9) | 3 (2.3) | |
| Other blunt injury | 4 (2.4) | 6 (4.7) | |
| Arrived from, n (%) | | | *0.896* |
| Scene | 134 (79.8) | 104 (80.6) | |
| Outside hospital | 34 (20.2) | 25 (19.4) | |
| Initial SBP, n (%) | | | *0.390* |
| < 90 mmHg | 57 (33.9) | 50 (38.8) | |
| ≥ 90mmHg | 111 (66.1) | 79 (61.2) | |
| Initial SBP, mean (IQR) (mmHg) | 104 (80, 127.8) | 96 (80, 122) | *0.434* |
| Initial MAP, mean (IQR) (mmHg) | 78.7 (62.6, 106.5) | 74 (59.2, 94.6) | *0.194* |
| Initial GCS, median (IQR) | 13 (7, 14) | 12 (6, 14) | *0.039** |
| Initial lactic acid, median (IQR) (mmol/L), | 5.5 (3.9, 7.9) | 6.4 (4.5, 10.0) | *0.016** |
| Known associated injuries, AIS ≥ 3, n (%) | | | |
| Head and neck | 50 (29.8) | 40 (31.0) | *0.817* |
| Face | 2 (1.2) | 0 (0) | *0.214* |
| Chest | 148 (88.1) | 104 (80.6) | *0.075* |

| Variables | SCV group (n = 168) | FV group (n = 129) | *p-value* |
|---|---|---|---|
| Abdomen | 113 (67.3) | 102 (79.1) | *0.024** |
| Pelvis | 103 (61.3) | 58 (45) | *0.005** |
| Extremity | 22 (13.1) | 19 (14.7) | *0.686* |
| ISS, median (IQR) | 38 (34, 45) | 38 (29, 50) | *0.937* |
| Underlying diseases, n (%) | 88 (52.4) | 50 (38.8) | *0.020** |

*$p < 0.05$

SCV, subclavian vein; FV, femoral vein; SBP, systolic blood pressure; MAP, mean arterial pressure; GCS, Glasgow coma scale; AIS, abbreviated injury scale; ISS, injury severity scale; IQR, interquartile range.

Table 5
Patient's outcomes and complications related to abdomen or pelvic trauma

| Variables | SCV group (n = 168) | FV group (n = 129) | *p-value* |
|---|---|---|---|
| RBC transfusion, median (IQR) (units) | | | |
| Within 4 h | 10 (6, 14) | 10 (6, 15) | *0.992* |
| Within 24 h | 12 (8, 18.8) | 12 (8, 20) | *0.663* |
| FFP transfusion, median (IQR) (units) | | | |
| Within 4 h | 8 (6, 12) | 8 (6, 16) | *0.472* |
| Within 24 h | 12 (8, 18) | 12 (8, 21.5) | *0.624* |
| Procedure for hemorrhagic control, n (%) | | | *0.761* |
| Operation | 58 (34.5) | 51 (39.5) | |
| Intervention | 54 (32.1) | 35 (27.1) | |
| Both | 39 (23.2) | 29 (22.5) | |
| Conservative care | 17 (10.1) | 14 (10.9) | |
| Complications related to trauma, n (%) | | | |
| VTE, n (%) | 9 (5.4) | 27 (20.9) | *< 0.001** |
| DVT, n (%) | 7 (4.2) | 27 (20.9) | *< 0.001** |
| PTE, n (%) | 5 (3) | 1 (0.8) | *0.238* |
| CLABSI, n (%) | 0 (0) | 0 (0) | *N/A* |
| ICU LOS, median (IQR), (d) | 9 (4, 18.8) | 7 (4, 17) | *0.643* |
| Ventilator days, median (IQR), (d) | 4 (2, 11.8) | 4 (1, 10) | *0.826* |
| Hospital LOS, median (IQR), (d) | 32 (17.3, 49) | 26 (14.5, 45.5) | *0.062* |
| 30-day mortality, n (%) | 23 (13.7) | 27 (20.9) | *0.098* |

* $p < 0.05$

SCV, subclavian vein; FV, femoral vein; RBC, red blood cell; FFP, fresh frozen plasma; VTE, venous thromboembolism; DVT, deep vein thrombosis; PTE, pulmonary thromboembolism; CLABSI, central line-associated bloodstream infection; ICU, intensive care unit; LOS, length of stay; IQR, interquartile range.

[Insert Table 4 here]

[Insert Table 5 here]

# Factors associated with mortality

Multivariable logistic regression identified several predictors of 30-day mortality (Table 6**)**. Significant predictors included: age (OR 1.036, 95% CI 1.017–1.056, $p < 0.001$), lower initial MAP (OR 0.987, 95% CI 0.976–0.998, $p = 0.019$), lower initial GCS (OR 0.807, 95% CI 0.744–0.876, $p < 0.001$), higher lactate (OR 1.199, 95% CI 1.098–1.308, $p < 0.001$), and severe injuries of the head and neck (OR 3.210, 95% CI 1.542–6.681, $p = 0.002$), chest (OR 2.673, 95% CI 1.367–5.226, $p = 0.004$), or extremities (OR 14.993, 95% CI 3.848–58.419, $p < 0.001$) were significant predictors. However, catheter insertion site (FV vs. SCV) was not significantly associated with 30-day mortality (OR 1.017, 95% CI 0.733–1.411, $p = 0.918$).

Table 6
Risk factors for 30-day mortality (1) **Entire population**

| **Variables** | **Odds Ratio** | **95% CI** | ***p-value*** |
|---|---|---|---|
| Age | 1.036 | 1.017–1.056 | **< 0.001** |
| Initial MAP (mmHg) | 0.987 | 0.976–0.998 | 0.019 |
| Initial GCS | 0.807 | 0.744–0.876 | **< 0.001** |
| Initial lacerate (mmol/L) | 1.199 | 1.098–1.308 | **< 0.001** |
| €MAC insertion site (FV vs. SCV) | 1.017 | 0.733–1.411 | 0.918 |
| Head and neck, AIS ≥ 3 | 3.210 | 1.542–6.681 | 0.002 |
| Chest, AIS ≥ 3 | 2.673 | 1.367–5.226 | 0.004 |
| Extremity, AIS ≥ 3 | 14.993 | 3.848–58.419 | **< 0.001** |
| MAP, mean arterial pressure; GCS, Glasgow coma scale; AIS, abbreviated injury scale; MAC, Multi-lumen access catheter; FV, femoral vein; SCV, subclavian vein; CI, confidence interval. | | | |
| €MAC insertion site was entered into the regression model; however, it was not retained in the final stepwise model, indicating no significant association with 30-day mortality | | | |
| Bold text indicates statistical significance. | | | |
| (2) **Patients with abdomen or pelvis AIS** ≥ 3 | | | |

| Variables | Odds Ratio | 95% CI | *p-value* |
|---|---|---|---|
| Age | 1.044 | 1.019–1.070 | *<0.001* |
| Initial MAP (mmHg) | 0.978 | 0.961–0.995 | *0.012* |
| Initial GCS | 0.815 | 0.735–0.902 | *<0.001* |
| Initial lacerate (mmol/L) | 1.187 | 1.055–1.336 | *0.004* |
| Chest, AIS ≥3 | 0.344 | 0.116–1.019 | *0.054* |
| Extremity, AIS ≥3 | 0.144 | 0.024–0.851 | *<0.001* |
| €MAC insertion site (FV vs. SCV) | 1.193 | 0.773–1.842 | *0.425* |
| RBC transfusion within 4 h (unit) | 1.129 | 1.067–1.195 | *<0.001* |

MAP, mean arterial pressure; GCS, Glasgow coma scale; AIS, abbreviated injury scale; MAC, Multi-lumen access catheter; FV, femoral vein; SCV, subclavian vein; CI, confidence interval.

€MAC insertion site was entered into the regression model; however, it was not retained in the final stepwise model, indicating no significant association with 30-day mortality

In patients with severe abdominal or pelvic injuries (AIS ≥ 3), independent predictors of 30-day mortality included age (OR 1.044, 95% CI 1.019–1.070, $p < 0.001$), lower initial MAP (OR 0.978, 95% CI 0.961–0.995, $p = 0.012$), lower initial GCS (OR 0.815, 95% CI 0.735–0.902, $p < 0.001$), higher lactate (OR 1.187, 95% CI 1.055–1.336, $p = 0.004$), and higher RBC transfusion volume within 4 h (OR 1.129, 95% CI 1.067–1.195, $p < 0.001$). Catheter insertion site was not significantly associated with mortality (OR 1.193, 95% CI 0.773–1.842, *p = 0.425*), similar to the overall cohort (Table 6).

[Insert Table 6 here]

# Discussion

The “Golden hour” is central to prehospital trauma care, highlighting the time-sensitive nature of trauma resuscitation (10). This principle extends to the in-hospital phase, emphasizing the need for early resuscitation in patients with hemorrhagic shock. Therefore, rapid vascular access is a prerequisite for immediate resuscitative volume expansion, including massive transfusion. Accordingly, most trauma guidelines recommend establishing two large-bore peripheral intravenous access as the first-line approach (1, 11). However, in practice, this is difficult in patients with profound circulatory collapse or with patient-specific factors such as obesity or ethnicity-related anatomic variation (2, 3, 12). In addition, polytrauma with multiple extremity injuries often precludes peripheral IV access, limiting adequate line placement. Thus, intraosseous (IO) access has emerged as an alternative, offering rapid insertion and high success (13, 14). In this cohort, 6.6% of patients required IO access owing to failed large-bore peripheral IV placement, highlighting practical vascular access difficulties during trauma resuscitation.

However, its role in massive transfusion remains controversial. IO infusion rates are consistently lower than intravenous rates, even under high pressure, limiting large-volume blood product delivery (15). The Trauma Quality Improvement Program best practice guidelines emphasize blood product delivery via rapid infuser and blood warmer, as blood viscosity increases with decreasing temperature (16, 17). However, evidence supporting the efficacy and safety of combining IO access with rapid infusion devices or warming systems is lacking, though technically possible. Therefore, short, large-caliber CVCs such as MAC should be considered “trauma lines” for optimal volume resuscitation in patients with hemorrhagic shock.

For patients with abdominal or pelvic trauma, some experts recommend placing at least one intravenous catheter in a superior vena cava tributary, given the potential for IVC injury (7). However, robust data are lacking on the optimal insertion site for trauma-dedicated CVCs. Moreover, several factors including patient’s anatomic injury pattern and physician’s experience should guide CVC site insertion. Our study addresses this gap by evaluating clinical outcomes by CVC insertion site in trauma patients, providing practical insights for vascular access during hemorrhagic shock resuscitation.

In the overall cohort, patients in the FV group had lower initial MAP and higher lactate levels, and more severe associated injuries than those the SCV group. This suggested femoral access was preferentially selected for patients with greater physiological derangement. Prior studies similarly show subclavian CVCs were more often inserted in patients with higher systolic blood pressure and better GCS than femoral CVCs during trauma resuscitation (18). Meanwhile, severe pelvic injuries were more frequent in the SCV group, likely reflecting avoidance of catheter placement at the injury site. Most transfusions in this study were administered via the MAC using a rapid infusion device, with no significant difference in RBC or FFP transfused between the SCV and FV groups.

Catheter-related thromboembolic complications were identified by retrospective review of abdominal/chest computed tomography (CT) scan or lower-extremity CT angiography. Femoral access was associated with a significantly higher incidence of venous thromboembolism, likely attributable to local venous stasis and endothelial injury related to femoral catheter placement (19). Notably, although DVT was significantly more common in the FV group, PTE occurred in the SCV group. Although upper-extremity DVT was not detected in our cohort owing to the lack of routine screening, previous studies report SCV catheter–related thrombosis in up to one-third of severely injured trauma patients (20). These findings suggested that the higher DVT incidence in the FV group does not imply SCV access is free from thrombotic risk, which in some cases may progress to PTE. Although FV catheterization is a known risk factor for catheter-related infection, no CLABSI events were observed in this study. A previous randomized controlled trial demonstrated that FV catheterization independently increased CLABSI risk nearly fivefold (21). Thus, it could be hypothesized that CLABSI risk is higher when MACs are inserted under urgent circumstances. However, a recent multicenter cohort study by Cosme et al. found no significant difference in CLABSI incidence across femoral, subclavian, and internal jugular sites, attributed to improved insertion techniques, chlorohexidine-based disinfection, and timely catheter removal (22).

Thirty-day mortality was significantly higher in the FV group, however, this difference is likely attributable to the greater physiological derangement at presentation in the FV cohort, rather than the insertion site itself. Consequently, multivariable logistic regression identified age, initial MAP, GCS, and severe injuries as independent mortality predictors, whereas catheter insertion site was not significantly associated with outcome. These findings indicated that patient physiology and injury burden, rather than the CVC site, are the primary determinants of survival in trauma patients with hemorrhagic shock.

Both SCV and FV access showed distinct complication profiles in this cohort, consistent with prior reports (18). SCV was associated with more failed catheterizations and mechanical complications (pneumothorax, malposition, and hemorrhage), while FV was technically less challenging yet complicated by arterial placements. Notably, timely CVC access remains critical for initiating transfusion during trauma resuscitation (23), highlighting the role of CVCs as “trauma lines.” Although hemorrhagic events were rare, one fatal mediastinal vessel injury illustrates the potential severity of arterial trauma. Outcomes depend on injury site, patient stability, and catheter diameter. Thus, although large-caliber CVCs are often necessary, inadvertent arterial injury can be catastrophic, requiring meticulous technique, early recognition, and multidisciplinary management (24).

To assess whether MAC placement above the diaphragm improves survival in patients with abdominal or pelvic trauma with possible IVC or iliac vein injuries, a subgroup analysis was performed in patients with AIS ≥ 3. Similar to the entire cohort, baseline characteristics demonstrated that patients in the FV group had lower GCS and higher lactate levels, indicating greater physiologic derangement at presentation than patients in the SCV group. Despite these differences, transfusion volume, hemorrhagic control procedures, ICU/hospital stay, and 30-day mortality did not significantly differ between the two groups. Multivariable logistic regression showed catheter insertion site was not significantly associated with mortality. These findings suggested that the site of MAC insertion alone does not determine outcomes in patients with severe abdominal or pelvic trauma; survival is driven primarily by patient physiology and injury burden.

In pelvic fractures, most venous bleeding arises from large presacral venous plexus disruption or arterial injury. The internal iliac artery and its branches are the vessels most frequently affected by blunt pelvic trauma (25, 26). Blunt IVC injury is also rare. Choi et al. reported that only 28 of 7,365 patients (0.4%) with ISS > 15 had blunt IVC injury (27). Similarly, a large multicenter registry analysis confirmed IVC injury in only o.6% of all patients with abdominal trauma (28). Given this low prevalence, routine supradiaphragmatic catheterization solely to avoid potential IVC injury appears limited, and other clinical factors should guide insertion site selection. In this study, only four patients in the FV group required additional intraoperative internal jugular MAC insertion by an anesthesiologist after confirmed IVC injury. This finding highlights the importance anesthesiologist collaboration during trauma resuscitation and surgery to adapt vascular access strategies dynamically to the patient’s physiology.

This study had several limitations owing to its retrospective nature. First, reliance on EMR data rather than trauma video review prevented detailed assessment of catheterization procedures. Second, the

single-center design may limit the generalizability of findings. Third, catheter-related thromboembolic complications were identified via retrospective review of CT scans, likely underestimating SCV- or FV-related thrombus incidence. Finally, the small sample size of patients with confirmed IVC injury highlighted the need for future multicenter studies to validate these findings. Despite these limitations, this is the first study to evaluate clinical outcomes based on trauma-dedicated CVC insertion site during trauma resuscitation, providing real-world data from a large trauma cohort.

# Conclusion

In conclusion, during trauma resuscitation, CVC insertion site selection should be determined primarily by the patient's physiological status and injury pattern, rather than insertion site alone. Both SCV and FV access have distinct complication profiles; however, they were not independently associated with mortality. Accordingly, vascular access decisions should be clinical context-specific, considering potential complications. These decisions must be integrated into a coordinated, team-based resuscitation strategy.

# Abbreviations

| | |
|---|---|
| ATLS | Advanced Trauma Life Support |
| PIV | Peripheral intravenous catheter |
| CVC | Central venous catheter |
| MAC | Multi-lumen access catheter |
| ICU | Intensive care unit |
| RBC | Red blood cells |
| ISS | Injury Severity Score |
| MTP | Massive transfusion protocol |
| EMR | Electronic medical record |
| AIS | Abbreviated Injury Scale |
| MAP | mean arterial pressure |
| CLABSI | central line-associated blood stream infection |
| SCV | subclavian vein |
| FV | femoral vein |

| | |
|---|---|
| IO | interosseous |
| DVT | deep vein thrombosis |
| PTE | pulmonary thromboembolism |

# Declarations

*Ethics approval and consent to participate*

The requirement for obtaining informed consent was waived by the Institutional Review Board (IRB) of Ajou University Hospital (IRB No. AJOUIRB-DB-2025-218) owing to the observational nature of the study.

*Consent for publication*

Not applicable.

*Competing interests*

The authors declare that they have no competing interests.

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Formal analysis; JK, JM

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Supervision; JM

Visualization; JK, JeK, SK, JY, JM

Writing– original draft; JK, JM

Writing– review & editing; JK, JeK, JM.

All authors reviewed the final manuscript.

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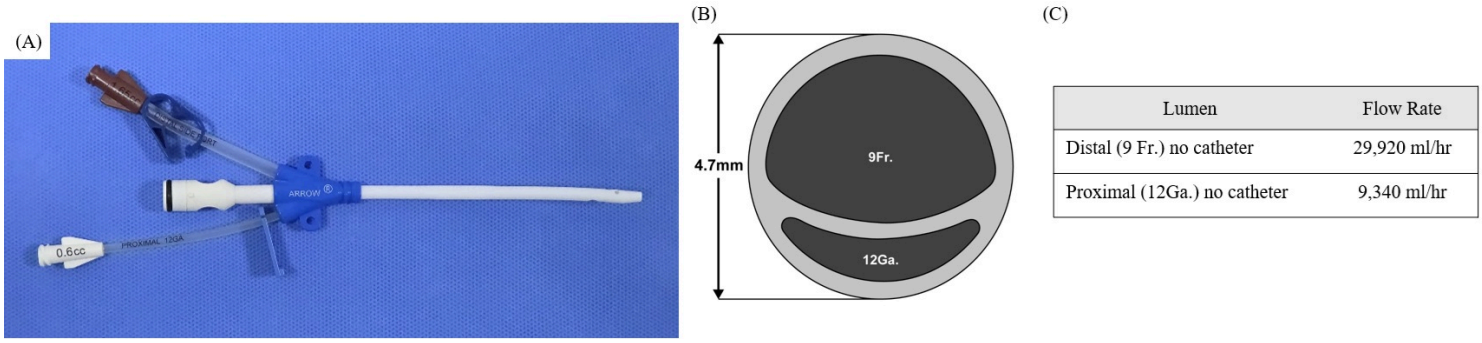

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# Figures




| Lumen | Flow Rate |
|---|---|
| Distal (9 Fr.) no catheter | 29,920 ml/hr |
| Proximal (12Ga.) no catheter | 9,340 ml/hr |

**Figure 1**

(A) The 9-Fr Multi-lumen access catheter (MAC, Arrow, Teleflex, PA, USA); (B) Cross section of the MAC; (C) Flow rate of the MAC (*in vitro*) using 100 cm head-height gravity saline flow rates

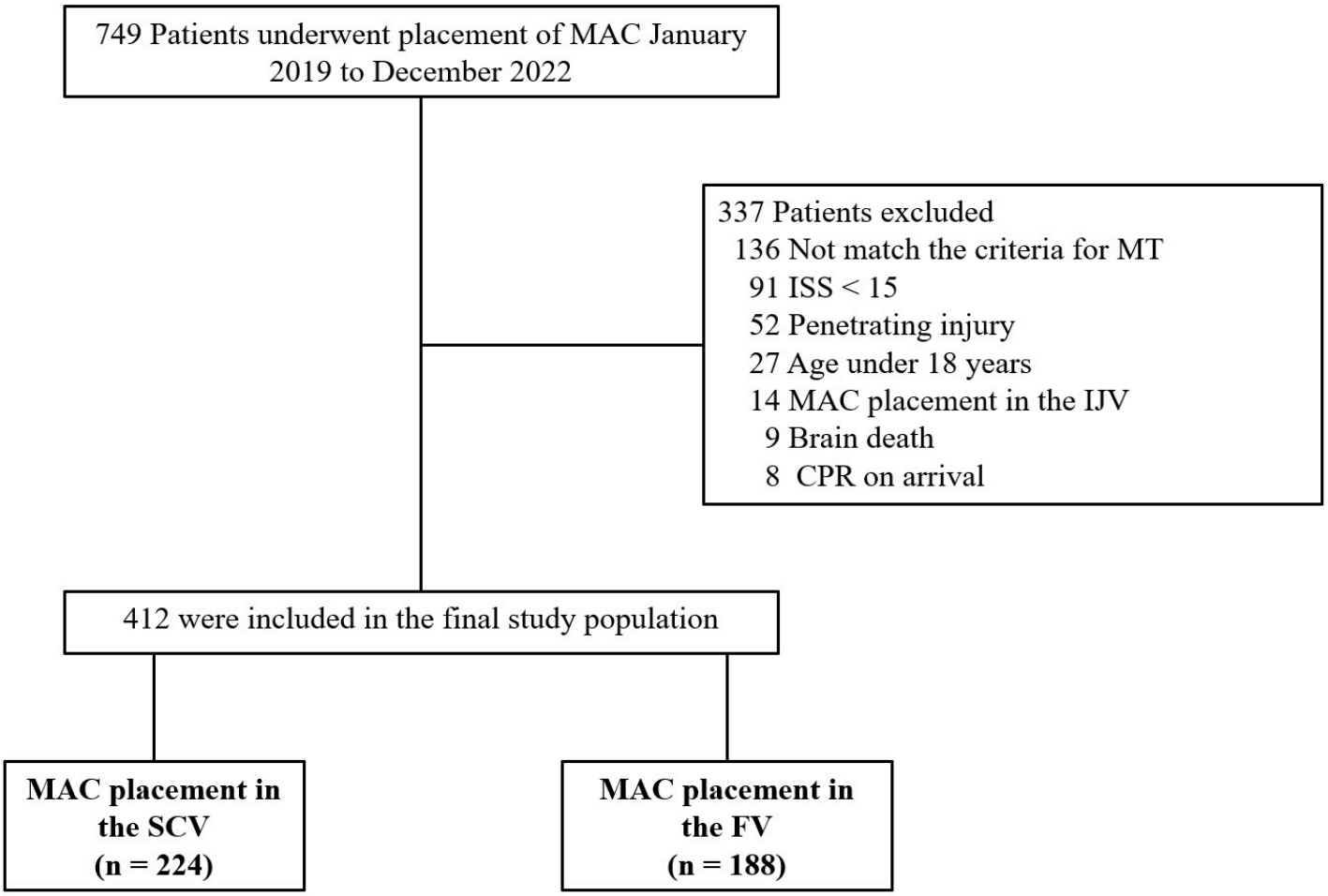



**Figure 2**

Flow chart of the study population

# Supplementary Files

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- Supplementary1.jpg