Introduction

Pelvic fractures are typically the result of high-energy trauma and are associated with bladder and urethral injury (BUI). Pelvic injuries can include symphysis pubis diastasis, displaced pubic and sacrum fractures, iliac wing and ischium fractures, sacroiliac (SI) joint displacement, or any combination of these injuries. Common mechanisms of injury include motor vehicle and motorcycle crashes, motor vehicle collision with a pedestrian, and individuals involved in industrial accidents and falls. One of the most concerning complications related to pelvic bone fracture is BUI [1-3], however, it is often undiagnosed in the Emergency Department. This is because most BUs occur after major trauma involving multiple organs where clinicians...
focus on more life-threatening problems [4,5], and classic signs and symptoms associated with BUI, such as blood at the meatus or gross hematuria, are sometimes absent [6]. Additionally, computed tomography scans are often inadequate at detecting bladder injuries, it has been reported that there is an accuracy of only 50-60% [7,8]. Furthermore, because BUI is uncommon, it is often not suspected.

Failure to diagnose BUI early can lead to significant morbidity and mortality. It has been reported that when a diagnosis delayed, patients may develop a wide variety of complications including septic shock, pelvic abscess, peritonitis, myonecrosis of the thigh, and bladder entrapment [9,10]. In addition, Bjurlin et al [1] reported that BUI was a cause of extended stays in the hospital wards and intensive care units.

The key to a good prognosis and outcome lies in the early detection of BUI. Thus, key clinical risk factors may aid the clinician in deciding which patients are at highest risk of BUI and in the most need of further evaluation. We hypothesized that, considering the anatomical location of the bladder, certain radiological findings such as symphysis pubis diastasis and pubic bone fracture, and certain laboratory findings such as hematuria and an abnormal delta neutrophil index (DNI), may be risk factors for BUI in cases of pelvic bone fracture. In this study, we aimed to identify the risk factors associated with BUI in patients with pelvic bone fracture. In addition, because BUI is often found when performing surgery such as preperitoneal pelvic packing (PPP), we aimed to determine whether there was a relationship between PPP and BUI diagnosis.

Materials and Methods

This retrospective study was approved by the institutional review board (IRB) of Wonju Severance Christian hospital (IRB no.: CR320180). The medical data of patients with pelvic bone fracture from January 2015 to June 2020 were collated. Data were collected prospectively and analyzed retrospectively. The data was analyzed anonymously, therefore, informed consent was waived. The inclusion criteria were patients who were greater than 18 years and had documented pelvic bone fracture. Patients in whom the BUI status could not be confirmed were excluded from this study.

Bladder injury was diagnosed using computerized tomography (CT), cystography, or direct observation. Urethra injury was diagnosed using urethrography. Patient data were divided according to the presence or absence of BUI and the 2 groups were compared.

Using the medical data bank, the variables analyzed included age, sex, cause of injury, initial vital signs, Glasgow Coma Scale score, Injury Severity Score, Abbreviated Injury Scale (AIS) score, associated injury (1 or more injuries with an AIS ≥ 3 except AIS 5), performing PPP, presence of femur fractures, lumbar spine fractures, pelvic bone fractures (including symphysis pubis diastasis, SI joint dislocation, and pubic bone, acetabulum, ischium, ilium, sacrum, and open fractures), and laboratory results [hemoglobin, platelet count, DNI, lactate, blood urea nitrogen, and urine red blood cell (RBC) count/high power field (HPF)]. Symphysis pubis diastasis was defined as a symphyseal separation of more than 10 mm and a vertical shift of more than 5 mm [11]. Pelvic bone fractures were classified according to the Young-Burgess (YB) and Arbeitsgemeinschaft für Osteosynthesefragen (AO) classifications by an orthopedic surgeon specializing in pelvic bone.

For statistical analysis, the chi-square test, Fisher’s exact test, and Mann-Whitney U test were used to compare groups. To identify independent risk factors for BUI, multivariate analysis was performed using logistic regression. All statistical analyses were performed using SPSS Version 25.0 (IBM, Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation, and p < 0.05 indicated statistical significance.

Results

Out of 342 patients with pelvic bone fracture, there were 28 patients in whom the BUI status could not be confirmed, leaving data from 314 patients to be included in the study. There were 24 patients who had BUI, 16 patients had bladder rupture only, 5 patients had urethra injury only, and 3 patients had bladder and urethra injuries concomitantly. Among the 19 patients with bladder rupture, including 3 patients who had both injuries, 15 patients had extraperitoneal bladder rupture, and 4 patients had intraperitoneal bladder rupture (Figure 1). Among the 24 patients with BUI, 19 patients (79.2%) were male. Of these, 12 patients had bladder injury, 4 had urethra injury, and 3 had bladder and urethra injuries concomitantly. Among the female patients, 4 had bladder injuries only and 1 had a urethra injury only. The proportion of males in the BUI-present group was significantly higher than in the BUI-absent group. For both groups, pedestrian-vehicle collisions were the most common cause of injury. PPP was more frequently performed in the BUI-present group compared with the BUI-absent group. Among pelvic bone fracture findings, symphysis pubis diastasis and SI joint dislocation were significantly more frequent in the BUI-present group compared with the BUI-absent group. Among laboratory findings, DNI was higher in the BUI-present group compared with the BUI-absent group. In addition, a higher percentage of patients in the BUI-present group had a urine RBC count/HPF ≥ 30 compared with the BUI-absent group (Table 1).

When the 2 groups were classified according to YB and AO fracture classifications and analyzed, there was no
difference between the 2 groups. However, the proportion of anteroposterior compression (APC) type injuries in the BUI-present group was higher than in the BUI-absent group (Table 2).

The logistic regression model using variables that were noted in the univariate analysis showed that symphysis pubis diastasis and a urine RBC count/HPF ≥ 30 were independent risk factors associated with BUI (Table 3).

Of those with BUI, 15 patients were diagnosed at the trauma bay, and 9 patients had a delayed diagnosis (Figure 2). Among these 9 patients, extraperitoneal bladder rupture was diagnosed in 2 patients during open reduction and internal fixation. In 2 other patients, extraperitoneal type BUI was diagnosed during PPP, and 1 of these patients exhibited a 5 cm laceration (Figure 3A). In a 5th patient, bladder rupture was not initially observed because of significant bleeding during PPP. However,
a 2nd operation to remove tapes revealed a laceration in the anterior wall of the bladder (extraperitoneal type rupture), which was subsequently repaired (Figure 3B). In a 6th patient, extraperitoneal and intraperitoneal type bladder ruptures were detected during PPP, and in a 7th patient, intraperitoneal bladder rupture was found during exploratory laparotomy due to hemoperitoneum and repaired. An 8th patient was diagnosed with extraperitoneal bladder rupture, and a 9th with urethra injury, through diagnostic testing after admission.

**Discussion**

Lower urinary tract injuries related to pelvic bone fracture include bladder rupture, injuries of the bladder neck, and urethral injury. In this study, the overall incidence of BUI among patients with pelvic bone fracture was 7.6%, consistent with previous observations between 6.8% and 25% as reviewed by Ziran et al [9]. Among all pelvic bone fractures in this current study, 5.1% had a concomitant bladder rupture, 1.6% had a urethral injury, and 1.0% had a bladder and urethra injury concomitantly, consistent with previously reported observations [1,9,12,13]. Extraperitoneal and intraperitoneal bladder ruptures...
occurred in 79%, and 21% of all pelvic bone fracture cases, respectively; this was also consistent with previously reported observations [12,14,15]. Gross hematuria and blood at the meatus indicates a high likelihood of BUI [5]. The presence of these signs in patients with pelvic fracture and BUI warrants further evaluation. However, these signs are sometimes absent on physical examination, necessitating a more thorough laboratory workup, such as urine RBC count. Although gross hematuria is strongly indicative of BUI, Carroll and McAninch [12] reported the presence of gross hematuria in only 82% of patients. In addition, although blood at the meatus occurs frequently with BUI, it has been reported that up to 57% of patients will not manifest evidence of urethral injury [9]. Furthermore, certain conditions, such as the presence of Foley catheters in patients transferred from another hospital or external hemorrhage in the groin or pelvic area, may obscure these signs. In this current study, more than 50% of the patients who visited the trauma center were referred from an outside facility [13]. For this reason, more objective variables, including urine RBC count, were used. A previous study suggested that a urine RBC count/HPF ≥ 50 was a risk factor for genitourinary injury with pelvic bone fractures [15]. In our hospital, if the urine RBC count/HPF was ≥ 30, it was reported in the urine analysis. Therefore, in our study, the analysis was conducted by dividing it by 30 and a urine RBC count/HPF ≥ 30 was an independent predictor.

Symphysis pubis diastasis and SI joint dislocation have been reported predictors of bladder injury [14,16]. In addition, superior and inferior pubic rami and symphysis pubis diastasis have been predictors of urethral injuries [14,17]. Bjurlin et al [1] reported that fracture of the symphysis pubis was associated with bladder and urethral injuries. In this current study, symphysis pubis diastasis and SI joint dislocation were significantly associated with BUI in univariate analysis, suggesting that BUI is likely to occur if the force of injury was applied from the anterior to posterior. However, only symphysis pubis diastasis independently predicted BUI in this study.

BUIs are most commonly caused by traffic accidents, although they can also occur after falls or blow injuries. Bjurlin et al [1] reported that motor vehicle collisions, pedestrians getting struck by vehicles, and motorcycle collisions were more likely to cause BUI-associated pelvic fractures. In this current study, the causes of injury were similar between the BUI-present and BUI-absent groups, with accidents involving a pedestrian being the most common cause in both groups. This reflected the geographical coverage area of the trauma center, where there were many rural areas and road maintenance was necessary.

Extraperitoneal bladder ruptures are primarily due to shear forces that occur during trauma to the pelvis. Occasionally, these injuries are the result of perforation by bony spicules [18] and usually involve the anterolateral aspect [19]. Intraperitoneal bladder rupture results from severe blunt lower abdominal or pelvic trauma to a distended or full bladder. Urethral ruptures are primarily due to the result of major shearing forces at the prostatomembranous junction, where the prostate apex is avulsed from the urogenital diaphragm [18]. Associated urethral injury in women with pelvic fractures is rare, due to its short length, mobility, and lack of attachments to the pubic symphysis [9,20]. Female urethral injuries are typically not due to shearing forces, as with the male urethra injuries, they are due to direct laceration from sharp edges of fracture fragments [18]. The reported incidence of urethra injuries with pelvic fractures in a large-scale retrospective study ranged from 1.6% to 25% in males, and from 1% to 6% in females [1]. Consistent with this, urethra injury was more common in males than females in this current study. However, it is unclear whether this was due to the difference in the mechanisms of injury between males and females, or because more than 70% of the patients admitted yearly to this trauma center have been men [13].

The rate of PPP was higher in the BUI-present group compared with the BUI-absent group when univariate analysis was performed. This was explained by the high proportion of patients with unstable pelvic bone fractures requiring PPP in the BUI group, and because extraperitoneal bladder rupture could be discovered upon performing PPP. Notably, in 1 patient whose BUI was initially missed due to heavy bleeding during PPP, extraperitoneal bladder rupture was discovered during a follow-up operation. Although PPP is not an independent risk factor for BUI, extraperitoneal bladder ruptures should be checked for during PPP and follow-up operations, and repaired intraoperatively.

The DNI is a numerical value indicating the degree of infection as well as the degree of acute inflammatory response resulting from trauma-induced tissue damage and hemorrhage [21]. Therefore, a higher DNI would be expected in the BUI-present group, reflecting more severe tissue damage due to BUI, compared with the BUI-absent group. However, DNI was not significantly higher in the BUI-present group in this study.

Pelvic bone injuries are classified according to the direction of the force of injury, and YB and AO classifications are commonly used. YB classification categorizes pelvic fractures into lateral compression, APC, and vertical shear type. The APC and lateral compression types are sorted further into Types A, B, and C with increasing degree of severity. This aids the trauma surgeon in gauging the hemodynamic stability of the patient and the orthopedic surgeon in determining the bony stability of the pelvis. Bjurlin et al [1] suggested that the incidence of bladder and urethral injuries is similar for each of the 3 common types of pelvic fractures. However, another study demonstrated that urethral injury is more common in open book pelvic injury [17]. In this study, bladder and urethral injuries occurred similarly between the 2 groups, however, APC type fractures were more...
common in the BUI-present group.

Open pelvic fractures are devastating injuries and associated with higher mortality and morbidity. In addition, bladder and urethra injuries are more common with open pelvic fracture [18]. However, we report no difference in open fracture between the 2 groups in this study.

Ziran et al [9] reported that 23% of BUIs were missed during the initial diagnosis in their study. In this current study, the proportion of delayed diagnoses were higher (37.5%).

Intraperitoneal bladder rupture is accompanied by severe abdominal symptoms and can be captured on an initial computed tomography scan (e.g., as a discontinuity of the bladder wall), therefore, the possibility of a missed diagnosis is low compared with extraperitoneal bladder rupture. Thus, in this study, most patients with a delayed diagnosis of BUI had extraperitoneal bladder rupture, which was observed and repaired during open reduction, PPP, or a follow-up operation. When performing surgery, such as open reduction or PPP for pelvic bone fracture treatment, the bladder should be checked and repaired during the same surgery.

This study has several limitations. Firstly, it was based on a retrospective analysis of the records of patients treated at a single institution. Secondly, it was limited by a small number of patients in the BUI-present group due to the rare nature of pelvic bone fracture-associated BUI. In addition, the patients in this study were treated by various trauma and orthopedic surgeons during the study period. Despite these limitations, this study is meaningful because it included key variables, such as PPP and laboratory data (including urine RBC count, creatinine, and DNI) as well as radiological findings related to BUI.

Conclusion

In conclusion, patients who sustained a pelvic bone fracture and displayed symphysis pubis diastasis and/or a urine RBC/HPF ≥ 30 were at an increased risk of BUI. Therefore, further workup for assessment of BUI should be considered for these patients. In addition, most patients with delayed diagnosis of BUI showed extraperitoneal bladder rupture, which was diagnosed during open reduction, PPP, or a follow-up operation. Therefore, the bladder should be checked during these surgeries and repaired immediately.

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Author Contributions

Conceptualization: JWK, MJK, YUC, HJS, HJC, JYJ, KSB, and KMK. Methodology: JWK, JYJ, HJS, and KMK. Formal investigation: JWK, MJK, HJC, and KMK. Data analysis: JYJ, and KMK Writing original draft: YUC, and KMK. Writing - review and editing: JWK, MJK, YUC, HJS, HJC, JYJ, KSB, and KMK.

Conflicts of Interest

The authors declare no conflict of interest

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Ethical Statement

Not applicable.

Data Availability

All relevant data are included in this manuscript.

References


