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Postoperative gait analysis and hip muscle strength in patients with pelvic ring fracture

Masafumi Kubota [a], Kenzo Uchida [b,*], Yasuo Kokubo [b], Seiichiro Shimada [a], Hideaki Matsuo [a], Takafumi Yayama [b], Tsuyoshi Miyazaki [b], Daisuke Sugita [b], Shuji Watanabe [b], Hisatoshi Baba [b]

[a] Division of Physical Therapy and Rehabilitation Medicine, University of Fukui Hospital, Fukui 910-1193, Japan
[b] Department of Orthopaedics and Rehabilitation Medicine, Faculty of Medical Sciences, University of Fukui, Fukui 910-1193, Japan

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ABSTRACT

The aims of present study were (1) to determine changes in kinematic and kinetic variables at 3 and 12 months after open reduction and internal fixation (ORIF) of pelvic ring fracture and (2) to determine the factor(s) associated with gait disorders that correlate with gait parameters measured at 12 months after surgery. Nineteen patients with pelvic ring fractures underwent ORIF and examined at 3 and 12 months postoperatively. The study also included a similar number of age-matched control subjects. Peak hip abduction angle, peak hip extension moment in the stance, peak hip abduction moment, and peak ankle plantarflexion moment at 3 months after ORIF were significantly lower than the respective control values. At 12 months, complete recovery was noted in peak hip abduction moment and peak ankle plantarflexion moment, whereas the recovery in peak hip abduction angle and peak hip extension moment in the stance was partial. The existence of neurological lesions and strength asymmetry of hip abductor and adductor at 3 months post-ORIF correlated with decreased peak hip abduction moment after ORIF. Our results highlighted characteristic gait patterns up to 12 months after ORIF for pelvic fracture, and these patterns correlated with neurological lesion and weakness of hip abductor and adductor muscles.

1. Introduction

Pelvic ring fractures occur as high-energy injuries and are usually associated with multiple concomitant injuries [1–3]. Open anatomical reduction of unstable pelvic ring fractures combined with rigid internal fixation and early mobilization is the standard current treatment for such injuries [4]. Several groups have reported the short- and long-term outcomes of open reduction and internal fixation (ORIF) for pelvic ring fractures, and most patients are reported to achieve excellent or good results based on the results of clinical functional scores [5,6]. Although poor quality reduction, associated injuries [6], and neurologic injury correlate with poor functional results [5], the impact of postoperative rehabilitation management has not been documented in detail.

Traumatic injuries are often associated with muscle injuries, and in the case of unstable pelvic fractures, with contusion of the muscles directly around the hip joint. In addition, surgical management of pelvic ring fractures also sometimes involves extensive dissection of the large muscles around the hip joint [7,8]. Normal function of the hip joint during walking requires sufficient muscle function and range of motion around the hip joint, therefore, persistent gait disorders several years after surgery are not rare [9–11]. Previous outcome studies of patients with pelvic ring fractures subjectively divided the gait category using Majeed score, and only one study [12] reported reductions in gait velocity and step length in patients with pelvic fractures after ORIF compared with normal subjects. To our knowledge, however, there are no reports of quantitative gait changes in patients with pelvic ring fractures treated with ORIF.

We hypothesized that ORIF for pelvic ring fracture results in a characteristic recovery of gait pattern based on kinematic and kinetic variables. Testing of this hypothesis should provide a better assessment of the short- and middle-term effects of this surgery and also provide important information for the design of proper rehabilitation programs after surgery for pelvic ring fracture. Furthermore, identification of factors associated with poor gait ability might help establish postoperative rehabilitation protocols that prevent such outcome. The present study was designed for the following purposes: (1) to determine changes in kinematic and kinetic variables at 3 and 12 months after ORIF for pelvic ring

* Corresponding author at: Department of Orthopaedics and Rehabilitation Medicine, Faculty of Medical Sciences, University of Fukui, Matsuoka-Shimoaizuki 23, Eiheiji, Fukui 910-1193, Japan. Tel.: +81 776 61 8383; fax: +81 776 61 8125.
E-mail address: kuchida@u-fukui.ac.jp (K. Uchida).

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fracture and (2) to determine the factor(s) associated with gait disorders that correlate with gait parameters measured at 12 months after surgery.

2. Patients and methods

2.1. Participants

The study subjects were 18 patients from 39 patients with pelvic ring fractures who were treated by ORIF at our hospital between January 2005 and June 2010. The following criteria excluded the remaining 21 patients: (1) concomitant acetabular fractures ($n = 7$), (2) severe head or spinal cord injuries ($n = 3$), (3) fractures of the femur, tibia, fibula or calcaneus ($n = 6$), and (4) follow-up of less than one year or declined participation ($n = 5$). Table 1 lists the characteristics of the enrolled patients. The study group consisted of 11 males and 7 females, with a mean age at the time of injury of 51.2 ± 19.7 years (±SD), mean height of 162.1 ± 6.8 cm, and mean body weight of 55.2 ± 8.6 kg. We also included a control group of 30 age- and sex-matched healthy volunteers who were recruited from several sources in the community (21 males and 9 females, age: 46.7 ± 17.5 years, height: 163.7 ± 7.4 cm, body weight: 57.9 ± 12.3 kg).

2.2. Surgical treatment and rehabilitation

All patients underwent ORIF of the pelvic ring fracture by the same surgeons (YK, TY, TM). The surgical approaches to the pelvis were tailored to each patient based on the particular pattern of the injury, location of the fracture, associated injuries, and the presence or absence of cutaneous injury. According to the conventional program in our rehabilitation department, postoperative rehabilitation commenced on the first or second postoperative day with active-assistive and passive range of motion exercises. Patients with unstable pelvic ring fractures maintained non-weight bearing status on the injured side until 6–8 weeks after ORIF. They were then allowed partial weight-bearing walking with crutches. Progressive resistive exercises for the injured hip musculature were initiated at two weeks after ORIF. Physical therapy was discontinued when patients were able to walk independently without aid. Patients were instructed to perform a daily home exercise program that included strengthening of the lower extremities and trunk muscles, stretching of the lower extremities, and ambulation training.

2.3. Fracture classification and postoperative radiographic and clinical evaluation

Pelvic ring fractures were classified according to the AO-Orthopaedic Trauma Association (OTA) classification regimen [13]. Classification was based on preoperative examination of the anteroposterior, iliac oblique, and obturator oblique radiographic views of the pelvis and fractured acetabulum. The radiological result was graded by the maximum residual displacement in the posterior and anterior pelvic ring injuries as; excellent for 0–5 mm, good for 6–10 mm, fair for 11–15 mm and poor for more than 15 mm of displacement or established nonunion [14]. The functional outcome was assessed using the scoring system described by Majeed [15], which is based on the clinical findings and carries a maximum total score of 100.

2.4. Gait analysis

Gait was analyzed at 3 and 12 months after ORIF in the patient group and once in the control group, using the VICON 370 system (Vicon Peak, Oxford, UK). The system comprises ten cameras that cover the area required for a complete gait cycle, and four force plates (Advanced Mechanical Technology Inc., Watertown, MA) placed in the middle of a 10-meter walkway. All cameras were calibrated before data collection, and the sampling rate was set at 60 Hz. Fifteen reflective markers were placed over known anatomic landmarks on both sides (sacrum, anterior superior iliac spine, middle thigh, knee, middle leg, ankle, heel, and toe of each foot) according to the VICON Clinical Manager protocol. Data were obtained while the subject was standing in an upright position to calculate joint centers. Afterward, the subject was asked to walk barefoot along the 10-meter laboratory walkway at self-selected walking pace. Patients with severe drop foot walked with AFO (ankle foot orthosis). After a few practice trials, 3 trials were recorded. The gait variables were expressed as percentages of the gait cycle. The assessed spatiotemporal variables included walking velocity, step length, step width, and cadence. The distance parameters were normalized by dividing their values by the subject's height. The kinematic and kinetic variables of the affected extremity in the patient group and of both extremities in the control group were collected. The joint moment was normalized by dividing its value by the subject's weight.

2.5. Muscle strength

The strength of the hip flexor, abductor and adductor muscles was measured by the same investigator at 3 and 12 months after ORIF using a handheld dynamometer (μTas F-1, Anima Corp., Tokyo, Japan). The validity and intertester reliability of this technique have been confirmed previously for the assessment of muscle strength of the lower extremity [16,17]. Hip flexor muscle force was tested with the subject sitting with 90° flexion of the hip and knee joints. The end piece of the dynamometer was applied to the anterior surface of the thigh just proximal to the femoral condyles. Hip abductor and adductor muscle forces were tested with the subject in supine position and the hip joint in neutral extension, abduction, and rotation and with the knee extended. The end piece of the dynamometer was applied to the lateral and medial surfaces of the thigh just proximal to the lateral condyles of the femur. A research assistant helped to stabilize the body parts proximal to the tested limb segment. Patients performed maximum isometric contraction for 3 seconds against the dynamometer, which was stabilized by the examiner using the included belt that anchors the device. Three separate trials were performed on each leg. The strength values on both sides as well as the asymmetry in strength, were expressed as the ratio of the affected side over the unaffected side.

Table 1
Characteristics of patients.

Patient	Sex	Age (yrs)	AO classification	Associated injury	Cause of injury	Surgical approach	Neurological lesion	Radiographic grade	Clinical score
1	M	43	C1	Bladder rapture	Sports	AEP + Pfa	None	Excellent	96
2	M	54	B2	Multiple rib fractures	Major crushing	AEP + Pfa	None	Excellent	89
3	M	74	C1	Spleen trauma	Fall from height	AEP + Pfa	None	Excellent	92
4	M	63	B1	Lumbar transverse process fracture	Fall from height	Pfa + posterior	None	Good	92
5	F	50	C1	Hemothorax, rib fracture	MVA	IL	L5, S1 hypesthesia	Good	83
6	M	71	C1	Abdomen injury, lumbar fracture	Fall from height	IL	L5, S1, motor + sensory lesion	Fair	72
7	M	70	A2	Pneumothorax	MVA	AEP	None	Excellent	86
8	M	22	A2	None	Major crushing	Pfa	None	Excellent	96
9	F	67	A2	Hemothorax	MVA	AEP	None	Excellent	91
10	F	30	A2	Hemothorax, orbital fracture	MVA	AEP	None	Excellent	91
11	F	71	B2	None	MVA	Posterior	None	Excellent	78
12	M	25	C1	Humerus fracture	MVA	Pfa + posterior	L4, L5, S1, motor + sensory lesion	Good	74
13	M	50	C1	None	Fall from height	AEP	None	Fair	89
14	F	22	B2	None	MVA	Posterior	None	Excellent	96
15	F	18	C1	Hemothorax, rib fracture	MVA	Pfa + posterior	L5 hypesthesia	Excellent	91
16	F	64	C1	None	Fall from height	AEP + Pfa	None	Fair	86
17	M	67	C1	Hemothorax, chronic subdural hematoma	MVA	IL	None	Good	92
18	M	61	B2	Hemothorax, rib fracture, clavicle fracture	MVA	Posterior	None	Good	87

MVA: motor-vehicle accident; AEP: Anterior extraperitoneal approach; Pfa: Pfannenstiel approach; IL: Ilioinguinal approach.