Predictors of outcome of floating knee injuries in adults

89 patients followed for 2–12 years

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ABSTRACT – Of the 98 floating knee injuries that were consecutively treated from 1987 to 1997, 89 patients were available for analysis. There were 80 males and 9 females, ranging from 15 to 70 years old. Average follow-up was 5 (2–12) years. Injury severity scores ranged from 18 to 45. 21 fractures were intra-articular. 55 fractures were open. Substantial comminuted and segmental fractures occurred in 57 cases and 35 cases, respectively. Multivariate analysis showed that increasing age was associated with delays in bony union and full weight bearing ability. An increase in the number of pack years smoked at the time of injury predicted the likelihood of knee stiffness, delays in bony union and full weight bearing ability. Higher injury severity scores were associated with delayed full weight bearing ability. The presence of open fractures predicted the likelihood of knee stiffness and delayed full weight bearing ability. Comminuted fractures were associated with malunion, and segmental fractures with delayed bony union. Using the outcome of floating knee injuries as fair or poor, according to Karlström and Olerud's criteria, we constructed a preoperative prognostic scoring scale which showed a sensitivity of 0.72 and a specificity of 0.90.

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Ipsilateral fractures of the femur and tibia in the adult, or floating knee injuries, are serious injuries with a high risk of complications. Besides being caused by high-energy trauma with extensive skeletal and soft tissue damage, they are also associated with potentially life-threatening injuries of the head, chest and abdomen (Veith et al. 1984). Complications attributable to floating knee injuries include infection, excessive blood loss, fat embolism, malunion, delayed or nonunion, knee stiffness, prolonged hospitalization and inability to bear weight (Fraser et al. 1978, Veith et al. 1984). Although several studies (Karlström and Olerud 1977, Fraser et al. 1978, Bansal et al. 1984, Veith et al. 1984, Letts et al. 1986, Behr et al. 1987, Bohn and Durbin 1991, Anastopoulos et al. 1992) have reported the outcome of these injuries after operative or nonoperative treatments, little attention has been paid to the factors that may correlate to outcome in floating knee injuries.

We report our experience of treating these fractures over a 10-year period at a level 1 trauma center. We performed multivariate analysis to determine poor predictors of outcome. From these data, we developed a preoperative prognostic scoring scale and it was tested for sensitivity and specificity.

Patients and methods

We retrospectively reviewed all patients with floating knee injuries treated at the Tan Tock Seng Hospital over a 10-year period from 1987 to 1997. We included femoral fractures distal to the subtrochanteric level and ipsilateral tibia fractures involving the condyles and shaft. By retrieving relevant data from the case records, we found that 98 patients had been consecutively treated during this period. At the time of review in 1999 by an independent examiner, 3 patients had died of concomitant injuries, and 6 patients were lost to follow-up. Therefore, 89 patients (80 men) were available for analysis (Table 1). The mean follow-up was 5 (2–12) years. Their mean age was 37 (15–70) years. 32 cases occurred in the third decade of life, 27 in the second decade of life and 9 patients had co-existing illnesses. Road traffic accidents accounted for 75 cases; of these, 43 involved a motorcycle, 20 an automobile, and 12 pedestrians. The remaining injuries were from falls at industrial worksites.

All our patients had injury severity scoring (Baker et al. 1974) performed on admission. The mean score was 26 (18–45). 40 patients had scores between 20 and 30. Associated substantial injuries included: contralateral and/or other ipsilateral lower limb fractures in 24 cases, upper limb fractures in 15, head/neck injuries in 20, thoracic injuries in 13, abdominal/spinal injuries in 4 and pelvic injuries in 2 cases. Substantial injuries were defined as injuries graded as 2 or more on the Abbreviated Injury Scale (Baker et al. 1974). Other major sequelae noted were hypovolemic shock in 13 cases, disseminated intravascular coagulation in 2, stress ulcers in 2, compartment syndrome necessitating fasciotomy in 6, and posttraumatic stress reaction in 4 cases.

The classification of the fractures was based on that of Letts et al. (1986). Type A fractures are both diaphyseal and closed. Type B fractures are closed, metaphyseal in one bone and diaphyseal in the other. Type C fractures are closed, one bone has an intra-articular extension of the fracture, regardless of the site in the other bone. Type D fractures include one open fracture, regardless of the site. Type E fractures include both open fractures, regardless of the location. With this method, 22 cases were classified as type A, 2 as type B, 10 as type C, 35 as type D, and 20 cases as type E.

Using the AO/ASIF classification of fractures (Müller 1991), there were 66 diaphyseal fractures of the tibiae and 73 diaphyseal fractures of the femur. Among the diaphyseal tibial fractures, there were 19 AO type A, 29 AO type B, and 18 AO type C fractures. Among the diaphyseal femoral fractures, there were 46 AO type A, 14 AO type B, and 13 AO type C fractures. 23 were proximal tibial fractures and 16 were distal femoral fractures. Of the proximal tibial fractures, 7 were AO type A, 14 were AO type B, and 2 were AO type C. Of the distal femoral fractures, 7 were AO type A, 2 were AO type B, and 7 were AO type C.

Comminution was classified with Winquist et al.'s method (1984), who first described the classification of femoral fractures. We considered types III and IV comminuted fractures as substantially comminuted. This was extrapolated to our definition of substantial comminution among fractures of the tibia. 57 cases had substantial fracture comminution of the tibia, femur, or both. 35 cases had segmental fractures of the tibia, femur, or both. 25 patients had both segmental and significantly comminuted fractures. All injuries of pedestrians had substantial comminution, or segmental fractures, or both.

55 floating knee injuries were open, grade I in 10 cases, grade II in 16, and grade III in 29 (17 grade IIIA; 8 grade IIIB; 4 grade IIIC). 32 patients had open fractures of the tibia; 3 patients had open fractures of the femur; 20 had both open fractures of the femur and tibia. Of the 20 patients with open fractures of both their tibiae and femur, 3 sustained near-amputation proximal to their knees.

Using the soft tissue injury classification recommended by the AO/ASIF (Rüedi 1991), we found 11 IC1, 6 IC2, 13 IC3, 4 IC4, 10 IO1, 16 IO2, 17 IO3, 8 IO4, and 4 IO5. The extent of muscle and tendon involvement was as follows: 27 MT1, 30 MT2, 17 MT3, 8 MT4, and 7 MT5. Neurovascular injury included: 78 NV1; 7 NV2; 1 NV3; 3 NV5.

21 patients had intra-articular extension of their fractures. 4 had intra-articular fractures of both their tibiae and femur. 12 had fractures of the tibial condyles, 5 had femoral intercondylar fractures. 11 of the 21 intra-articular fractures were open or compound: grade I in 2 cases, grade II in 2 cases,and grade III in 7.

On admission, all patients were given analgesics and splintage. Anti-tetanus toxoid was given if the fractures were open. The wounds were inspected in the emergency room and dressed. No further inspection was done until the patients reached the operating room. Therapeutic antibiotics, consisting of penicillin, cloxacillin and gentamicin, were started. For closed fractures, prophylactic cefazolin was given at induction of anesthesia.

Table 1. General table

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
16	m	18	1,2	0	0	0	0	2	2	0	2	7	0	0	0°–130°	0	0	0	0
21	m	27	1,4	1f	0	1t	0	1	2	0	4	5	0	0	0°–110°	1af	1	0	0
21	m	34	5	2t	0	1t	0	3	2	2	3	16	0	0	0°–110°	1bf	1	13t	2,7
21	m	18	1,8	0	0	0	0	2	1	0	3	8	0	0	0°–130°	0	0	0	0
22	m	25	7	0	0	0	1t	2	2	0	5	5	0	0	0°–115°	1c	1	11	0
24	m	21	1,7,8	0	0	1t	0	1	1	1	4	6	0	0	0°–120°	1b	1	4,8	0
24	m	45	1,3,4	2ft	0	0	0	2	2	3	7	9	0	1	10°–100°	2bc	2	3	0
24	m	18	2,8	0	1t	0	0	2	2	0	4	4	0	0	0°–115°	0	1	0	0
24	m	18	1,2	3t	0	1t	0	2	2	0	3	5	0	0	5°–115°	1bc	1	0	0
25	m	43	1,7,8	1ft	1t	0	0	2	2	0	7	3	0	0	0°–115°	0	1	16	0
26	m	24	1,4	0	0	2	0	1	1	4	6	17	1f	1	15°–105°	2ab	2	10	0
26	m	25	0	3ft	0	0	0	3	3	2	4	16	0	0	0°–110°	1bc	1	2,6,13ft	1
28	m	34	1	1t	0	2	0	2	2	0	4	5	0	0	10°–120°	1bd	1	0	0
28	m	21	1,2,3	0	0	1t	0	2	2	0	3	6	0	0	0°–130°	0	0	0	0
28	m	18	2,8	1t	0	0	0	2	1	0	3	7	0	0	5°–115°	0	1	0	0
31	m	27	1,2	3t	0	1t	0	3	2	0	3	5	0	0	0°–120°	1b	1	5,9	0
31	m	25	7	2t	1f	0	0	1	2	0	4	9	0	0	0°–110°	0	1	6,13t	1
31	m	18	1,2	2f	1t	0	0	1	1	5	5	7	0	1	10°–100°	2bc	2	6,10	0
32	m	25	7	0	0	1t	0	3	2	1	8	24	0	0	0°–110°	1c	1	13t	1,2
32	m	27	1,2	0	0	0	2	2	2	0	4	5	0	0	0°–115°	1ad	1	6	0
32	m	27	1,2	2t	0	0	0	1	2	0	3	8	0	0	0°–120°	0	1	4,5,14	0
34	m	25	3	3ft	1t	1t	0	3	2	0	5	8	0	0	5°–120°	0	1	2	0
35	f	18	1,2	3ft	2	2	2	3	3	15	9	17	1t	1	fused	3a	3	1,13ft	1,4
35	m	36	1,4,7	2t	1f	2	0	2	2	0	5	7	0	0	0°–115°	1bc	1	2,11	0
36	m	25	3	0	0	0	1t	2	2	0	3	3	0	0	0°–110°	1bf	1	0	0
36	m	18	1,2	3t	0	0	1t	3	2	6	12	p	1t	1	10°–100°	2bc	2	2,13t	6
36	m	25	7	0	0	0	1t	2	1	2	3	5	0	0	0°–120°	0	1	0	0
37	m	18	1,8	3t	0	1f	0	3	1	2	3	5	0	0	5°–115°	0	1	0	0
37	m	27	1,2,7	3t	0	1t	0	3	2	0	12	14	0	1	0°–95°	2cd	2	2	0
38	m	43	1,4,7	3t	1f	1f	0	3	2	6	14	16	1f	1	15°–105°	2ac	2	3,13t	2
39	m	45	1,3,4	3t	1t	1t	0	3	2	8	8	14	0	1	10°–110°	2bc	2	2,13t	1
41	m	18	1,2	0	0	1f	0	1	1	2	11	21	0	0	10°–120°	1bd	1	0	0
42	f	18	1,2,7	0	0	2	0	1	2	3	9	45	0	0	0°–110°	1bd	1	13t	1,3
43	m	25	0	3ft	2	2	0	3	2	0	6	9	2	1	15°–105°	2bc	2	2,10,13t	1
44	m	34	2,6	3ft	1f	2	0	3	2	0	8	10	0	0	0°–110°	1bd	1	6,7,13ft	1
46	m	25	7	0	1t	1t	0	3	2	0	9	9	0	0	5°–115°	1c	1	8,13t	2
46	m	34	1	2t	2	0	0	2	2	0	6	10	0	0	5°–120°	0	1	1,5	0
52	m	27	1,2,7	0	1t	2	0	1	1	20	8	23	1f	1	10°–100°	2cd	2	12	0
58	m	18	2,5	1ft	1f	1f	1f	1	1	0	3	14	2	1	15°–105°	2cd	2	8	0
60	m	36	1,3,4,7	3t	0	1f	0	3	1	0	5	5	0	1	0°–90°	2cd	2	6	0
61	f	18	2,4	0	0	1f	1t	3	2	0	7	22	0	0	0°–115°	1bf	1	15	0
66	m	25	0	3ft	1f	1f	1t	2	1	32	10	16	0	0	0°–110°	3be	3	2,13f	1,7
68	m	36	2,3,4	0	0	1t	0	1	1	0	34	50	0	0	0°–110°	1de	1	4,13f	1,2
68	m	25	0	3ft	1f	2	1f	3	3	0	–	–	–	–	–	–	–	1,6,17	5
62	m	18	2,8	2t	1f	2	1f	1	1	0	6	10	0	0	0°–110°	2bc	2	0	0
15	m	18	1,2	0	0	0	0	2	2	0	3	7	0	0	0°–130°	0	0	0	0
20	f	18	1,8	0	0	0	0	2	1	0	3	8	0	0	0°–130°	0	0	0	0
21	m	34	4	2t	0	1t	0	3	2	2	3	16	0	0	10°–120°	1a	1	13t	2,7
19	m	27	1,4	1ft	0	1t	0	1	2	0	4	5	0	0	0°–115°	1b	1	11	0
22	m	25	7	0	0	0	1t	2	2	0	5	5	0	0	10°–120°	1c	1	2	0
23	m	21	1,2,7	0	0	1t	0	1	1	3	5	6	0	0	0°–110°	1bd	1	4	0
24	m	18	1,2	0	1t	0	0	2	2	0	3	4	0	0	0°–110°	0	1	0	0
24	f	45	1,3,4	2ft	0	0	0	2	2	7	7	9	0	1	0°–90°	2bd	2	0	0
31	m	25	7	2t	1f	0	0	1	2	0	4	9	0	0	0°–110°	0	1	6,13t	1
30	m	27	1,2	3t	0	1t	0	3	2	0	3	5	1t	1	0°–90°	2ad	2	6	0
28	m	18	2,8	1t	0	0	0	2	1	0	3	7	0	0	0°–120°	0	1	0	0
27	m	21	1,2,3	0	0	1t	0	2	2	0	3	6	0	0	0°–130°	0	0	6	0
27	m	34	1	1t	0	2	0	2	2	0	4	5	0	0	0°–110°	1d	1	0	0
26	m	25	0	3ft	0	0	0	3	3	3	4	16	0	0	10°–120°	1ac	1	2,13ft	1
26	m	24	1,2	0	0	2	0	1	1	9	6	17	1f	1	0°–90°	2ad	2	8,10	0
25	m	43	1,4,7	1ft	1t	0	0	2	2	0	7	3	0	0	0°–110°	0	1	0	0
24	m	18	1,2	3t	0	1t	0	2	2	0	4	5	0	0	10°–120°	1bc	1	10	0
31	m	18	1,2	2f	1t	0	0	1	1	11	5	7	0	1	0°–90°	2bc	2	6	0
32	m	25	7	0	0	1t	0	3	2	3	8	23	0	0	0°–120°	1c	1	13t	2
32	m	27	1,2	0	0	0	2	2	2	0	4	6	0	0	0°–110°	1bd	1	11	0
33	f	27	1,2	2t	0	0	0	1	2	0	3	8	0	0	0°–110°	1f	1	4,14	0
34	m	25	3	3ft	1t	1t	0	3	2	0	5	8	0	0	0°–120°	1f	1	2	0
35	f	18	1,2	3ft	2	2	2	3	3	24	9	17	1t	1	20°–70°	3a	3	1,13ft	1

Table 1, continued

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
35	m	36	1,4,7	2t	1f	2	0	2	2	0	5	7	0	0	5°–115°	1ac	1	2	0
35	m	25	3	0	0	0	1t	2	2	0	3	3	0	0	0°–120°	1af	1	0	0
38	m	18	1,2	3t	0	0	1t	3	2	16	14	p	1t	1	0°–90°	2de	2	2,13t	6
37	m	25	7	0	0	0	1t	2	1	4	3	5	0	0	0°–115°	0	1	0	0
37	m	18	1,2	3t	0	1f	0	3	1	5	3	5	0	0	5°–115°	0	1	0	0
37	m	27	1,2,7	3t	0	1t	0	3	2	0	12	14	0	0	0°–110°	1bd	1	0	0
36	m	43	1,5,7	3t	1f	1f	0	3	2	20	14	16	1f	1	10°–110°	2ce	2	13t	2
39	m	45	1,3,4	3t	1t	1t	0	3	2	19	8	14	0	1	10°–110°	2cd	2	2,13t	1
41	m	18	1,2	0	0	1f	0	1	1	22	11	21	1f	1	0°–90°	2ce	2	0	0
42	f	18	1,2,3	0	0	2	0	1	2	5	9	45	0	0	0°–110°	1bd	1	13t	1,3
43	m	25	0	3ft	2	2	0	3	2	0	6	9	2	1	10°–100°	2d	2	2,10,13t	1
44	m	34	4,6	3ft	1f	2	0	3	2	0	8	10	2	1	0°–90°	2bd	2	6,7,13ft	1
45	m	25	7	0	1t	1t	0	3	2	0	9	9	0	0	0°–110°	1c	1	13t	2
46	m	34	1	2t	2	0	0	2	2	0	6	10	0	0	0°–110°	0	1	0	0
54	m	27	1,2,7	0	1t	2	0	1	1	28	8	23	1f	1	0°–90°	2b	2	0	0
59	m	25	0	1ft	1f	1f	1f	1	1	0	3	14	2	1	10°–100°	2b	2	0	0
60	m	36	1,2,3	3t	0	1f	0	3	1	0	5	5	0	1	5°–95°	2ac	2	6	0
61	m	18	2,5	2t	1f	2	1f	1	1	0	6	10	0	0	0°–110°	0	1	0	0
68	m	36	2,3,5	0	0	1t	0	1	1	0	34	50	0	0	0°–110°	1be	1	4,13f	1,2
70	m	25	0	3ft	1f	1f	1t	2	1	34	10	16	0	0	20°–100°	3bd	3	2,13f	1
63	f	18	2,4	0	0	1f	1t	3	2	0	7	22	0	0	50°–115°	1af	1	0	0

A Age at index operation (years)
B Sex
- m male
- f female

C Injury severity score
D Associated injuries
- 0 none
- 1 head/neck injury
- 2 facial injury
- 3 upper limb/clavicle injury
- 4 chest injury
- 5 abdominal/pelvic viscera injury
- 6 pelvic bony injury
- 7 other lower extremity injury
- 8 thoracic/lumbar spine injury

E Open/closed fractures
- 0 closed
- 1 grade I open [ft]
- 2 grade II open [ft]
- 3 grade III open [ft]

F Segmental fractures
- 0 not segmental
- 1 segmental in 1 bone [ft]
- 2 segmental in both bones

G Comminuted fractures
- 0 no significant comminution
- 1 comminution in 1 bone [ft]
- 2 comminution in both bones

H Intra-articular fractures
- 0 extraarticular
- 1 intraarticular in 1 bone [ft]
- 2 intraarticular in both bones

I Tibia treatment
- 1 intramedullary nail
- 2 plate
- 3 external fixator

J Femur treatment
- 1 intramedullary nail
- 2 plate
- 3 external fixator

K Number of pack years smoked
L Time-to-full weight bearing (months)
M Time-to-bony union (months)
- p pseudarthrosis

N Significant malunion
- 0 none
- 1 1 bone malunited [ft]
- 2 both bones malunited

O Significant knee stiffness
- 0 none
- 1 stiff knee

P Knee range of motion
Q Pain/subjective complaints
- a knee effusion/swelling
- b knee pain/stiffness
- c ankle pain/stiffness
- d limp
- e hip pain/stiffness
- f knee laxity
- 0 none
- 1 intermittent, slight
- 2 more severe symptoms impairing function
- 3 considerable functional impairment, pain at rest

R Gait walking ability
- 0 unimpaired
- 1 intermittent, slight impairment
- 2 restricted
- 3 need to use cane or crutch

S Complications
- 0 none
- 1 osteomyelitis
- 2 wound infection/pin-site infection
- 3 adult respiratory distress syndrome
- 4 fat embolism
- 5 pneumonia
- 6 hypovolemic shock
- 7 coagulopathy
- 8 significant anemia (< 7 g/dL)
- 9 septicemic shock
- 10 compartment syndrome
- 11 posttraumatic stress reaction
- 12 loosening of screw
- 13 nonunion [ft]
- 14 bleeding stress ulcer
- 15 cholangitis
- 16 urinary tract infection
- 17 arterial thrombosis

T Repeat surgery
- 0 none
- 1 bone grafting
- 2 nail conversion
- 3 plate conversion
- 4 knee arthrodesis
- 5 above-knee amputation
- 6 refused repeat surgery
- 7 dynamization of locking screw

[ft] (f = femur, t = tibia)

Table 2. Criteria for assessment of end results described by Karlström and Olerud (1977)

	Excellent	Good	Fair/acceptable	Poor
Subjective leg symptoms	Nil	Intermittent slight	More severe symptoms impairing function	Considerable functional impairment; pain at rest
Subjective knee or ankle symptoms	Nil	Intermittent slight	More severe symptoms impairing function	Considerable functional impairment; pain at rest
Walking ability	Unimpaired	Intermittent, slight impairment	Restricted	Uses cane or crutch
Work and sports	Same as before injury	Given up some sport; work same as before	Change to less strenuous work	Permanent disability
Malangulation, malrotation, or both	Nil	< 10°	10° to 20°	> 20°
Leg-length discrepancy	Nil	< 1 cm	1 to 3 cm	> 3 cm
Restricted joint mobility (hip, knee, or ankle)	Nil	< 10° at ankle, < 20° at hip, knee, or both	10° to 20° at ankle, 20° to 40° at hip, knee, or both	> 20° at ankle, > 40° at hip, knee, or both

All fractures were surgically corrected on the day of admission. Thorough wound debridement was done for open fractures before definitive skeletal stabilization. The choice of implants included intramedullary nails (e.g., retrograde femoral nails), various plate/screw constructs (e.g., 4.5 mm dynamic compression plates), and external fixators. Factors determining the choice of implants were the clinical state of the patients, presence of fat embolism, severity of open fractures, degree of comminution of fractures, presence of segmental fractures, and presence of metaphyseal or intraarticular fractures.

24 cases had an external fixator-plate construct, 24 had plating of both bones, 16 had a nail-plate construct, 16 had intramedullary nails inserted in both bones, 5 had external fixators placed on both bones, and 4 had an external fixator-nail construct.

3 patients who had near-amputation above their knees underwent an emergency vascular repair. As regards skin and soft tissue coverage, all open grade III B and C fractures had either pedicled flaps (gastrocnemius or soleus) or free flaps (rectus abdominis or latissimus dorsi) done. All grade III fractures of the femur and tibia had subsequent split skin-grafting performed when the wounds were clean.

Postoperative evaluation included length of hospitalization stay, postoperative complications, repeat surgery, time-to-bony union, time-to-full weight bearing, malunion, and knee stiffness. Bony union and malunion were assessed by examining the standing radiographs of the injured limb in 2 views. In this study, delayed union was defined as failure to see evidence of union on radiographs by 4–6 months (Rosen 1991). Nonunion was defined as the absence of clinical and radiographic signs of healing for the previous 3 months, at least 9 months after injury (Perry 1996). Malunion was defined as 10° or more of malrotation (internal/external), valgus/varus angulation, or anterior/posterior angulation. Substantial knee stiffness was defined as restricted knee mobility of 20° or more.

We used 7 standard criteria to assess outcome (Karlström and Olerud 1977; Table 2). For instance, patients had to fulfill all of the excellent criteria to be rated as such. Patients were rated as good outcome if they fulfilled all the good or excellent criteria. A fair or acceptable outcome was rated if the patient had at least 1 fair criterion fulfilled, and, no poor criterion. A patient who had 1 poor criterion was considered as a poor outcome.

Statistics

The preoperative variables that might have affected the final clinical outcome were analyzed statistically. The 8 baseline variables examined were age and sex of the patient at index surgery, smoking history at the time of injury, injury severity score, presence of substantial comminution, of segmental fractures, of intraarticular fractures, and presence of open fractures. A positive smoking history included patients who were smoking at the time of injury. The mean number of pack years smoked among the 89 patients at the time of injury was 3.7 (0–34). Continuous baseline variables were age, history of smoking (pack years, defined as number of cigarette packs smoked per day multiplied by the number of years smoked), and injury severity score. Categorical baseline variables were sex, comminution (no comminution, tibial/femoral comminution, or comminution in both tibia and femur), segmental fractures (none, 1 or more segmental fractures), intra-articular fractures (none, 1 or more intra-articular fractures), and open fractures (none, grade I/II, or grade III). Since there were only 6 patients who had segmental fractures involving both tibia and femur, segmental fractures were coded into 2 categories (none, 1 or more segmental fractures). This allowed sufficient sample size in each category to generate a reliable model. Similarly, as there were 4 patients who had intra-articular fractures of both tibia and femur, intra-articular fractures were coded into 2 categories (none, 1 or more intra-articular fractures).

The 4 final outcome measures in our study were malunion, knee stiffness, time-to-bony union, and time-to-full weight bearing. For the outcome measures of knee stiffness and malunion, unadjusted relative risk estimates were obtained for the 8 individual baseline variables. For time-to-bony union and time-to-full weight bearing ability, unadjusted relative risk estimates were obtained for the 8 individual baseline variables. The individual relative risk was presented with 95% confidence limits (Table 3).

Multivariate models were derived to determine predictors of outcome. As knee stiffness and malunion are binomial, logistic regression methods were used to derive the predictive models. On the other hand, as time-to-bony union and time-to-full weight bearing are continuous "time-to-event" outcomes, Cox regression analysis was used to determine predictors of time-to-bony union and -to-full weight bearing (Table 3).

Using the results of the multivariate analysis, a preoperative prognostic scoring scale was devised based on the presence or absence of significant predictors of outcome. If any variable predicted the final outcome (malunion, knee stiffness, time-to-bony union, or time-to-full weight bearing), it was included in the scoring scale. Some variables had greater effects on outcome. For example, 1 variable might predict more outcome measures than another. On the basis of the results of the multivariate analysis, the individual variables were given different weights in the calculation of the prognostic score. If the variable was predictive of 1 outcome measure, then it was assigned scores ranging from 1 to 2. If the variable was predictive of 2 outcome measures, scores ranging from 1 to 3 were assigned. Scores ranging from 1 to 4 would be assigned to the variable that predicted 3 outcome measures. The final preoperative prognostic score was then calculated by adding all the scores of the predictive variables. The scale was then compared for reliability (sensitivity and specificity) with standard criteria for assessment of end results (Karlström and Olerud 1977), to determine whether we could accurately determine the outcome of these injuries on initial admission. The sensitivity and specificity were calculated, using the outcome of floating knee injuries as fair or poor, according to Karlström and Olerud's criteria. Kappa values were also derived. We hypothesized that the higher the final preoperative prognostic score on the scale, the worse the final surgical outcome the patient would have.

Results

The mean length of stay in the hospital was 4 (1–24) weeks. Postoperative complications (Table 1) pertaining to the operative fixation of these fractures included wound infection (16 cases), osteomyelitis (4 cases), and fat embolism (6 cases). No osteomyelitis occurred among the fractures that had intramedullary nails inserted. All 6 cases of fat embolism had intramedullary nailing performed. The patients with fat embolism presented with disturbed consciousness, skin petechiae, tachycardia, low arterial oxygen tension (< 60 mm Hg), and pulmonary infiltrates on chest radiograph.

60 patients had delayed union. Of these , 28 went on to nonunion. 24 tibia fractures and 10 femoral fractures had nonunion. Repeat surgery (Table 1) consisted primarily of bone grafting and nail conversion. 10 cases had conversion to intramedullary nailing (from external fixators), of whom 3

Table 3. Relative risk estimates (adjusted relative risk estimates in parenthesis)

Variable	RR		95% Wald confidence limits			
Knee stiffness						
Age	1.0	(1.0)	0.99	(0.96)	1.1	(1.1)
Pack years	1.1	(1.1)	1.0	(1.0)	1.2	(1.2)
Injury severity score	1.1	(1.0)	1.0	(0.97)	1.1	(1.1)
Sex	0.82	(0.96)	0.19	(0.12)	3.6	(7.5)
Comminuted						
1 bone vs none	1.8	(0.71)	0.57	(0.014)	5.5	(3.5)
2 bones vs none	4.3	(2.4)	1.2	(0.48)	16	(12)
Intra-articular fracture	1.0	(0.74)	0.35	(0.12)	3.1	(4.6)
Segmental	3.1	(0.95)	1.2	(0.24)	8.0	(3.7)
Open/closed fracture						
Grades 1–2 vs closed	1.7	(1.9)	0.47	(0.3)	6.5	(11)
Grade 3 vs closed	6.7	(5.9)	2.0	(1.3)	22	(27)
Malunion						
Age	1.0	(0.93)	0.99	(0.84)	1.1	(1.0)
Pack years	1.1	(1.1)	1.04	(0.99)	1.2	(1.2)
Injury severity score	0.98	(0.96)	0.92	(0.86)	1.1	(1.1)
Sex	0.82	(12)	0.16	(0.13)	4.4	(>1000)
Comminuted						
1 bone vs none	2.8	(5.3)	0.53	(0.33)	15	(85)
2 bones vs none	15	(61)	2.7	(2.6)	82	(>1000)
Intra-articular fracture	2.2	(7.8)	0.70	(0.50)	7.0	(122)
Segmental	3.8	(2.5)	1.3	(0.3)	12	(21)
Open/closed fracture						
Grades 1–2 vs closed	0.5	(0.3)	0.1	(0.02)	2.7	(3.4)
Grade 3 vs closed	3.2	(2.5)	0.9	(0.5)	11	(14)
Time-to-bony union						
Age	0.97	(0.96)	0.95	(0.93)	0.99	(0.98)
Pack years	0.95	(0.94)	0.92	(0.90)	0.99	(0.98)
Injury severity score	1.0	(1.0)	0.98	(0.98)	1.0	(1.0)
Sex	1.8	(1.3)	0.89	(0.60)	3.6	(2.9)
Comminuted						
1 bone vs none	0.66	(0.93)	0.40	(0.51)	1.1	(1.6)
2 bones vs none	0.54	(0.8)	0.30	(0.38)	0.98	(1.5)
Intraarticular fracture	0.74	(1.5)	0.44	(0.74)	1.3	(3.1)
Segmental	1.1	(2.8)	0.72	(1.5)	1.8	(5.2)
Open/closed fracture						
Grades 1–2 vs closed	1.9	(0.86)	1.1	(0.44)	3.3	(1.7)
Grade 3 vs closed	1.0	(0.69)	0.62	(0.37)	1.8	(1.3)
Time-to-full weight bearing						
Age	0.96	(0.96)	0.94	(0.94)	0.98	(0.98)
Pack years	0.96	(0.96)	0.93	(0.92)	0.99	(1.0)
Injury severity score	0.98	(0.96)	0.95	(0.93)	1.0	(0.99)
Sex	1.2	(1.3)	0.61	(0.56)	2.5	(2.8)
Comminuted						
1 bone vs none	0.51	(1.1)	0.31	(0.58)	0.84	(2.0)
2 bones vs none	0.57	(1.1)	0.32	(0.53)	1.0	(2.1)
Intraarticular fracture	0.96	(1.3)	0.58	(0.66)	1.6	(2.6)
Segmental	0.78	(1.2)	0.50	(0.70)	1.2	(2.0)
Open/closed fracture						
Grades 1–2 vs closed	1.9	(1.9)	1.1	(1.0)	3.3	(3.7)
Grade 3 vs closed	0.77	(0.82)	0.46	(0.45)	1.3	(1.5)

also had supplemental bone grafting performed. 2 patients had bone grafting and conversion to compression plating (from external fixators). The remaining patients had bone grafting done to repair their pseudarthrosis. All repeat surgery cases eventually achieved bony union. 2 patients who refused bone grafting later developed pseudarthrosis of their tibia fractures. 1 patient had an above-knee amputation done because of thrombosis of the repaired popliteal artery and osteomyelitis of the tibia. The average time-to-bony union was 12 months, excluding the 2 patients with pseudarthrosis and 1 patient with above-knee amputation. All our patients, except one who had an above-knee amputation, achieved full weight-bearing ability after mean 6.5 (2–34) months. The 2 cases of pseudarthrosis who refused bone grafting were both able to bear full weight with some difficulty at 12 and 14 months, respectively after the injury.

17 patients had radiographic evidence of malunion of at least 10°. 6 and 13 patients had substantial leg-length discrepancy of more than 2 cm and 1 cm, respectively. 26 patients had restricted knee mobility of 20° or more (Table 1). 8 patients complained of symptoms of knee instability. 16 patients had substantial ankle pain and/or restricted ankle mobility of 10° or more. 4 patients reported substantial hip pain and/or restricted hip motion of 20° or more. 27 patients had substantial subjective complaints of joint pain, limp, or swelling affecting their activ-

ities of daily living.

On the basis of criteria (Table 2) for assessment of outcome (Karlström and Olerud 1977), 6 patients achieved an excellent outcome; 53 had good results; 25 patients had acceptable or fair outcome; 4 patients had a poor outcome. The patient who had an above-knee amputation was not assessed with these criteria.

Multivariate analysis (Table 3) of the findings in 88 of our patients was done to determine predictors of outcome. The patient who had an above-knee amputation was excluded from the analysis. This analysis showed that increasing age was associated with delays in fracture union and full weight bearing ability. An increase in the number of pack years smoked at the time of injury predicted the likelihood of knee stiffness , delays in fracture union and full weight bearing ability. Higher injury severity scores were associated with delayed full weight bearing ability. The presence of open fractures predicted the likelihood of knee stiffness and delayed full weight bearing ability. Comminuted fractures were associated with malunion, and segmental fractures were associated with delayed fracture union. Sex of the patient and presence of intra-articular fractures did not adversely affect the final outcome.

Using these predictors of outcome, we formulated a preoperative prognostic scoring scale (Table 4) for these patients, and compared them to Karlström and Olerud's criteria (1977). The preoperative prognostic scoring scale consisted of 6 variables: age, pack years smoked, injury severity scores, open fractures, segmental long bone fractures, and comminuted fractures. On the basis of the results of the multivariate analysis, the individual variables were given different weights in the calculation of the prognostic score (Table 4). Some factors such as age, pack years smoked, and open fractures had much greater effects on outcome. The number of pack years smoked predicted 3 outcome measures—i.e., knee stiffness, bony union time, and time-to-full weight bearing. Increasing age and open fractures had predictive effects on 2 outcome measures each. A final score on the preoperative scale of 6 was considered excellent; 7–9 good; 10–14 fair; 15–16 poor. Using this prognostic scoring scale, we had 10 excellent, 51 good, 25 fair, and 2 poor results.

Table 4. Preoperative prognostic scoring scale

Predictor/variable	Score
Age (years)	
46 and below	1
47–60	2
61 and above	3
Pack years smoked	
0	1
1–10	2
11–21	3
22 or more	4
Injury severity score	
36 and below	1
> 36	2
Open/closed fracture	
closed fracture	1
grade 1/2 open	2
grade 3 open	3
Segmental fracture	
none	1
1 or more	2
Comminuted fracture	
none	1
1 or more	2

Excellent 6, good 7–9, fair 10–14, poor 15–16

Sensitivity and specificity were used to compare the degree of agreement between the criteria of Karlström and Olerud (1977) and our preoperative prognostic scoring scale. 64 of the 88 cases were in agreement. Of the 24 cases where there was disagreement, the preoperative score predicted a more favorable outcome in 16 patients, and a less favorable outcome in the remaining 8. The kappa value was 0.52. Using the outcome of floating knee injuries as fair or poor, according to Karlström and Olerud's criteria, our preoperative prognostic scoring scale had a sensitivity of 0.72 and a specificity of 0.90.

Discussion

We believe our study is the first to report the predictors of floating knee injury outcome using multivariate models. We found that age, increasing number of pack years smoked at the time of injury, injury severity score, open fractures, segmental fractures, and comminuted fractures were associated with poor outcome. Smoking appears to be a very important factor predicting the outcome, and was thus given greater weight in the pre-operative scoring scale (Table 4). The history of smoking was based on status at the time of injury alone. Smoking status during follow-up was not taken into consideration in the analyses, because the relation between duration of follow-up and the likelihood of exposure would confound the results.

Treatment of floating knee injuries remains a challenging problem (Veith et al. 1984, Behr et al. 1987), as they are usually associated with extensive and severe soft tissue trauma and other serious associated injuries. We should aim for early rehabilitation and mobilization of the injured legs, so as to reduce complications and attain reasonably good functional outcome. Various authors (Hojer et al. 1975, Karlström and Olerud 1977, Veith et al. 1984) have reported excellent results following internal fixation of both fractures, and this method of treatment has been adopted by most orthopedic surgeons today. Operative stabilization was associated with less leg-length discrepancy, angular malunion, and need for a secondary procedure than conservative treatment in children with floating knee (Yue et al. 2000). However, although stabilization is an excellent treatment for patients with floating knee, the mortality and tibial fracture complications remain high (Ostrum 2000).

Several reports have dealt with the complications and functional results after treatment of these fractures, but few focus on the possible predictors of poor functional outcome. In two studies (Fraser et al. 1978, Bansal et al. 1984), the functional outcome was poor in the presence of articular fractures. Such fractures hamper knee movement and cause poor results. Since several baseline factors or variables may confound each other, multivariate analysis should be the best statistical method for predicting which factors might affect the outcome of surgical treatment.

We did not evaluate the choice of implants as one of the baseline variables because we felt that the surgical choice of implants would be determined partly by the patient's clinical state and the fracture characteristics—e.g., the presence of comminuted, segmental, and open fractures. We found that fashions in the method of fixation of floating knee injuries have changed considerably over the 10-year period from 1987 to 1997. The increase in the use of intramedullary nailing in segmental and open fractures seems to have contributed to a reduced incidence of nonunion and mal-union, and infection in our practice, although this statement can not be fully verified in our study.

Using the outcome of floating knee injuries as fair or poor, according to Karlström and Olerud's criteria, our preoperative prognostic scoring scale had a sensitivity of 0.72 and a specificity of 0.90. Our scoring scale had more patients (10 versus 6) with excellent results, slightly fewer patients (51 versus 53) with good results, and fewer patients (2 versus 4) with poor results. This is the first scale of its kind to try to prognosticate floating knee injuries in adults at initial presentation. Use of our preoperative prognostic scores in patients admitted with floating knee injuries may help to predict their outcome and thereby individualize treatment according to the patients' and fractures' characteristics. More aggressive and pre-emptive measures may be needed for potentially poor results in an attempt to change their final outcome. The ability of the preoperative scoring scale on floating knee injuries to predict the prognosis should be asssessed in a prospective series of patients. We think that the preoperative scoring scale can be improved by using a larger database, e.g., meta-analyses, thus increasing its reliability in predicting outcome after floating knee injuries.

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