THE “FLOATING KNEE” IN CHILDREN

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The term “floating knee” describes the flail joint resulting from fractures of the shaft or adjacent metaphyseal region of the ipsilateral femur and tibia; we have reviewed 15 children with this combined injury seen at the Winnipeg Children’s Hospital. All had been involved in motor vehicle accidents, eight having been struck while cycling; the biomechanics of such an injury have also been studied.

Treatment is difficult and the regimes varied. Results were poor when both fractures were treated non-operatively and we recommend that at least one of the fractures should be rigidly fixed.

The “floating knee” is the term applied to the flail knee joint segment resulting from a fracture of the shaft or adjacent metaphysis of the ipsilateral femur and tibia (Winquist 1984) (Fig. 1). In children, fractures through the growth plates of the distal femur or proximal tibia also may result in a floating knee, although the injury is uncommon and has not been widely studied.

In 1972 Winston reviewed 24 patients aged 15 to 78 years with such injuries. They were treated non-operatively and, despite many complications, the author felt that this treatment was safe. Höjer et al. (1976–77) noted a high incidence of open fractures and the need for a definite treatment plan. Karlström and Olerud (1977) reviewed 32 patients with ipsilateral fractures of the femur and tibia and noted better long-term results if rigid internal or external fixation of both fractures was used. In a very large series of 222 patients from 13 teaching hospitals in Quebec and Ontario the best overall results were obtained from the group who had both fractures internally fixed (Fraser, Hunter and Waddell 1978); these authors made a plea for more frequent use of external fixation and cast-bracing of fractured tibiae, as well as intramedullary nailing of femora. In a study by DeLee (1979) bracing was the definitive treatment in 15 patients aged 17 to 70 years with a floating knee, but shortening and malunion were common. More recently Veith, Winquist and Hansen (1984) have recommended “an aggressive operative approach to fixation” of both the femoral and tibial fractures. All these studies, however, have dealt primarily with the management of the adult patient. Because we found very few reports of the floating knee in children and because the injury is difficult to manage, we decided to review all 15 children with these injuries treated at the Winnipeg Children’s Hospital between 1973 and 1984.

PATIENTS AND METHODS

Associated injuries and methods of treatment were noted and the children were re-examined for possible complications. Limb lengths were measured clinically and, when appropriate, with scanograms.

A second objective was to evaluate the effects on the lower limb of a collision between a child cyclist and an automobile. The leg injured during impact was studied in varying degrees of flexion at the hip and knee; photographs were taken and the possible biomechanical forces of the accident analysed.
FINDINGS
Of the 15 children 11 were boys and 4 girls. All had been involved in a motor vehicle accident, and eight were riding a bicycle or motor-bike when struck; the collision had resulted in eight right and seven left ipsilateral fractures of the femur and tibia. At the time of injury the children’s ages ranged from 3 to 14 years with an average of 8.3 years.

Femoral fractures included nine of the shaft, one subtrochanteric fracture, two supracondylar fractures and three distal femoral epiphyseal injuries (two Salter–Harris Type II and one Type IV). Tibial injuries consisted of 11 of the shaft, three metaphyseal fractures and one Type I proximal epiphyseal fracture. Six children had open fractures of the tibia. three had open femoral fractures and two had open fractures of both femur and tibia which were also degloving injuries. Six children had associated head injuries, and all associated knee injuries occurred in the floating knee. One child had a peroneal nerve neurapraxia which resolved completely; other associated injuries are listed in Table I.

A variety of treatment regimes were employed: on the less severe open wounds, of which there were five, debridement and primary closure were performed; the two Grade III wounds were left open. The initial management of the fractures is shown in Table I. Two of the three femoral epiphyseal plate injuries were treated by open reduction and K-wire internal fixation. One Type II distal femoral epiphyseal injury was maintained by percutaneous K-wire fixation, and in two children external fixation of the tibia was used (Figs 2 and 3). Depending on the level of the femoral fracture, children were treated by a long-leg or hip spica cast; once the fracture was stable, patients were encouraged to walk.

Maintaining adequate reduction by traction was found to be more difficult in children over 12 years old, and complications were frequent in those children whose fractures were treated by traction alone. Three developed significant pin-track infection, and one subsequently developed osteomyelitis of the femur. Another child with a Grade III wound developed tibial osteomyelitis in spite of meticulous debridement and open management of the wound. Two patients had permanent limitation of knee movement due to severe soft-tissue injuries. Three
**Table I. Details of 15 patients with floating knee injury**

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Type</th>
<th>Other injury</th>
<th>Treatment Tibia</th>
<th>Treatment Femur</th>
<th>Complications</th>
<th>Time in hospital (days)</th>
<th>Follow-up (months)</th>
<th>Limb-length inequality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>M</td>
<td>D</td>
<td>Skull fracture</td>
<td>Closed reduction, percutaneous pins and cast</td>
<td>Skin traction</td>
<td>Overgrowth of affected limb</td>
<td>32</td>
<td>45</td>
<td>2 cm longer</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>M</td>
<td>A</td>
<td>Fractured contralateral tibia and fibula</td>
<td>Cast</td>
<td>Skin traction</td>
<td>None</td>
<td>30</td>
<td>39</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>M</td>
<td>A</td>
<td>Skull fracture</td>
<td>Skin traction</td>
<td>Skin traction</td>
<td>None</td>
<td>34</td>
<td>44</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>M</td>
<td>C</td>
<td>Fractured tibial spine</td>
<td>Cast and external fixation</td>
<td>Epiphyseal injury Type IV: ORIF</td>
<td>None</td>
<td>12</td>
<td>14</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>F</td>
<td>B</td>
<td>Concussion, contralateral femoral fracture</td>
<td>Cast</td>
<td>Skin traction</td>
<td>Femoral malunion</td>
<td>42</td>
<td>100</td>
<td>1.3 cm shorter</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>M</td>
<td>D</td>
<td>Fractured humerus</td>
<td>Cast</td>
<td>Balanced skeletal traction</td>
<td>Pin-track infection, femoral malunion, leg-length inequality</td>
<td>64</td>
<td>101</td>
<td>5 cm longer</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>M</td>
<td>C</td>
<td>Concussion</td>
<td>External fixation</td>
<td>Epiphyseal injury Type II: ORIF</td>
<td>Femoral epiphyseal bridge</td>
<td>22</td>
<td>22</td>
<td>1.5 cm shorter</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>M</td>
<td>A</td>
<td>Peroneal nerve neurapraxia</td>
<td>Cast</td>
<td>Trial of skin traction, balanced skeletal traction</td>
<td>Femoral malunion</td>
<td>55</td>
<td>138</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>14</td>
<td>F</td>
<td>C</td>
<td>Ruptured spleen</td>
<td>Cast</td>
<td>Epiphyseal injury Type II: percutaneous fixation</td>
<td>Premature closure of femoral epiphysis</td>
<td>18</td>
<td>18</td>
<td>1.2 cm shorter</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
<td>F</td>
<td>D</td>
<td>Fractured tibial spine</td>
<td>Cast</td>
<td>Balanced skeletal traction; IMN and cast</td>
<td>15 limitation of knee extension</td>
<td>50</td>
<td>124</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>M</td>
<td>E</td>
<td>Major muscle loss</td>
<td>ORIF and cast</td>
<td>ORIF and cast</td>
<td>Tibial non-union, femoral malunion, 10 limitation of knee extension</td>
<td>49</td>
<td>68</td>
<td>1.7 cm longer</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>M</td>
<td>E</td>
<td>Open fracture of ipsilateral patella and metacarpal fracture</td>
<td>ORIF with bone graft and external fixator</td>
<td>Balanced skeletal traction</td>
<td>Tibial osteomyelitis non-union ofibia and femur, limb-length inequality</td>
<td>202</td>
<td>38</td>
<td>6 cm shorter</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>F</td>
<td>D</td>
<td>Concussion</td>
<td>Trial of open reduction and cast; ORIF with plate</td>
<td>Balanced skeletal traction</td>
<td>Pin-track infection, femoral malunion</td>
<td>85</td>
<td>66</td>
<td>1.0 cm shorter</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
<td>M</td>
<td>B</td>
<td>Concussion</td>
<td>Cast</td>
<td>Skin traction</td>
<td>None</td>
<td>42</td>
<td>68</td>
<td>None</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>M</td>
<td>C</td>
<td>Fractured humerus</td>
<td>Epiphyseal Type I: cast</td>
<td>Femoral skeletal traction</td>
<td>Pin-track infection (superficial)</td>
<td>33</td>
<td>28</td>
<td>None</td>
</tr>
</tbody>
</table>

ORIF, open reduction with internal fixation
IMN, intramedullary nail
femoral fractures, one of which is shown in Figures 4 to 6. were treated by traction and proceeded to malunion; two of these were successfully treated by closed osteoclasis and skeletal traction, the third required open osteotomy and internal fixation. Bone grafting and plate fixation was required for two femora and two tibiae in three children. Five patients suffered leg-length inequality of 1.5 cm or more; two of these had distal femoral epiphyseal injuries which resulted in growth arrest. There were no deaths and none of the children developed fat embolism syndrome (Riska et al. 1976–77).

Mechanism of injury. By using photographs it was found that, with the hip and knee almost fully extended, the cyclist’s tibia and fibula are initially struck by the car’s bumper (Fig. 7); the child’s thigh is then struck by the front of the car (Fig. 8), throwing the child onto the bonnet, finally the child rolls off the bonnet, striking his head on the ground (Fig. 9). At this point the limb may be run over, resulting in possible degloving injuries.

DISCUSSION

Our purpose was to analyse, from both a clinical and an aetiological point of view, this uncommon combination of fractures in children. In a three-year study of patients admitted to our hospital with fractured femora only 4 of 154 (2.6%) had floating knees, and the average age of all the children admitted with fractured femora was 10.5 years compared with nine years for those with floating knees. Associated life-threatening injuries occurred in seven children and most were head injuries. Unlike many adults with this injury, the children we reviewed showed no evidence of the fat embolism syndrome.

We were concerned by the diversity in treatment, the number of problems in maintaining alignment with traction and the need for additional operative procedures because of malunion or non-union in our patients. To facilitate management we have designed a treatment protocol based on a new classification for the paediatric floating knee (Fig. 10). For a Type A injury in which both the femoral and tibial fractures are diaphyseal and

Fig. 7
The bumper of the car strikes the tibia of the cyclist’s extended leg, causing a fracture of the tibia and fibula. Figure 8. The cyclist is then struck on the thigh by the bonnet of the car, sustaining a fracture of the femur. Figure 9—The cyclist is thrown over the bonnet and on to the ground, sustaining head, chest or abdominal injuries and possible skin trauma from the wheels.

Fig. 10
Classification of the floating knee in children, showing the five types of injury.
closed, open reduction and internal fixation of the tibia and balanced skeletal traction for the femur is recommended. For Type B in which one fracture is diaphyseal, one fracture is metaphyseal and both are closed, open reduction and internal fixation of the diaphyseal fracture and balanced skeletal traction (or casting if possible) for the metaphyseal fracture is recommended. In the Type C injury in which one fracture is diaphyseal and the other is an epiphyseal displacement, it is recommended that reduction and internal fixation of the epiphyseal injury should be performed and the other fracture should be treated with traction or casting as indicated. In Type D in which one fracture is open with major soft-tissue injury, debridement and external fixation for the open tibial fracture with femoral traction for the open or closed fractured femur is recommended. For Type E in which both fractures are open with major soft-tissue injury, external fixation for the tibial fracture and traction or external fixation of the femur is recommended.

Our basic premise is that, with fractures of the ipsilateral femur and tibia, at least one fracture must be rigidly fixed and it is usually most appropriate for this to be the tibia. It is recommended that in open fractures with major soft-tissue injury (Type III) the wound should be left open but the fracture should be rigidly fixed to facilitate care of the soft tissues (Gustilo and Anderson 1976; Anderson and Gustilo 1980; Gustilo 1982).

We recognise that any treatment plan will have exceptions. If it is essential that the child should be mobilised immediately, internal fixation of both femoral and tibial fractures may be indicated. The type of internal fixation also may depend on the facilities available, the experience of the surgeon and the age of the child. In older children intramedullary nailing of the femur or tibia may be more appropriate than plate fixation. In children under six years of age it may be possible to obtain a stable closed reduction of the tibia which can be held with plaster while the femur is treated in traction. In contradistinction to current recommendations for the comparable fracture in adults (Winston 1972), it is not recommended that routine internal fixation of both fractures should always be performed since in children this can result in overgrowth of the fractured limb and may occasionally be complicated by osteomyelitis. Since fractures of the femur in children can be managed safely and effectively by traction, which can also accommodate any future limb-length overgrowth, it seems unwarranted to open this fracture unless necessary for the well-being of the child.

Photographic studies suggest the young child cyclist is most vulnerable to this injury simply because, if the limb is struck while the knee is extended, the tibia and the femur make contact with the bumper and bonnet. Collision between a car and a cyclist accounted for only 4.7% of isolated fractured femora in children, whereas over 50% of floating knees followed such injuries. Our review has also emphasised that a high degree of clinical vigilance is necessary to detect associated injuries in children presenting with floating knee (Brinkhous 1968); examination of the knee joint itself is difficult but not impossible, and in this small series four of the knees had a significant associated injury. At the time of fixation of one of the fractures, the other should be stabilised by an assistant so that the stability of the knee itself can be assessed.

**Conclusions.** The floating knee is rare in children and is usually caused when a child cyclist collides with a car. It is a high-velocity injury with a high incidence of major soft-tissue damage, open fractures and head injuries. Associated injuries are often missed and must be specifically sought, especially injury to the ipsilateral knee. Associated growth-plate injury, although uncommon, may result in growth disturbance. The combination of femoral and tibial fractures is difficult to treat and is fraught with complications if treated by traction alone. We recommend that at least one fracture should be rigidly fixed in all cases.

**REFERENCES**


