We identified 16 patients with a mean age of 56.5 years (31 to 86) from a large consecutive series of patients with proximal humeral fractures over a 15-year period, who had sustained a fracture with skin compromise after a blunt injury. The study group represented 0.2% of 7825 proximal humeral fractures treated during this period and all had a displaced Neer two-part fracture pattern. Two patterns of skin injury were identified: in ten patients there was skin penetration at the time of the original injury, and the other six patients initially had closed injuries. These six patients had fracture fragments penetrating the muscular envelope to lie subcutaneously producing either early skin tethering (two patients) or delayed skin penetration and sinus formation (four patients). The pattern of injury to the soft-tissue envelope and the fracture pattern were similar for all injuries. Treatment of these injuries was determined by the initial severity of the soft-tissue injury and the medical status of the patient. We currently favour open reduction and internal fixation of these fractures wherever possible, owing to the high rate of nonunion with non-operative management.

The most common soft-tissue injuries associated with proximal humeral fractures are neurological or vascular,1-3 and open fractures are rare.4 This is due to the thick soft-tissue envelope provided by the deltoid muscle, which protects the skin from penetration by fracture fragments. Open injuries are therefore most commonly associated with either penetrating trauma (most commonly blast or bullet injuries) or high-energy blunt trauma.5-7 These injuries occur more frequently in the military setting, or in urban populations with a high prevalence of gun-related crime. To our knowledge there are no reports of open proximal humeral fractures related to blunt trauma. This study evaluated the prevalence, injury patterns and treatment of a large consecutive series of patients studied over a prolonged period. Our aim was to assess whether particular fracture types were associated with open fractures and to provide guidelines for the assessment and treatment of these injuries.

Patients and Methods
Our unit provides the sole source of acute musculoskeletal trauma care to our local population, which is relatively stable and has a well-defined local catchment population according to census data. Between 1996 and 2010 all locally resident patients who sustained a proximal humeral fracture, treated either as an outpatient or an inpatient in this unit, were coded onto a trauma database. The demographic data, fracture configuration, mechanism of injury, soft-tissue injury, other associated injuries and primary treatment of these patients were evaluated. The mechanism of injury was classified into simple falls at or below standing height, falls from above standing height, sports injuries, road traffic accidents and all other causes. We excluded patients who were not locally resident, and those with peri-prosthetic fractures or pathological fractures due to tumour deposits. This yielded a cohort of 7825 injuries of which 2347 occurred in males and 5478 in females. The mean age was 64.3 years (13 to 103).

From the database we identified those patients who had an open fracture at the time of the initial injury, skin compromise caused by displaced fracture fragments, or who had developed skin breakdown related to their fracture within the first six weeks after injury. The grade of open fracture was assessed using the Gustilo and Anderson classification.8 The size of the wound and its anatomical location were recorded at the time of the initial assessment, and at surgical exploration. The fracture configuration was assessed by the senior author (CMR) using the Neer classification system,9 and also according to the pattern of displacement of the major fracture fragments.
The rarity of this injury and the heterogeneity of the injury pattern and population of patients who sustained the injury dictated that a definite protocol of treatment was not formulated for these injuries during the study period. However, for injuries with initial skin penetration we performed excision of the open wound, debridement of all contused and damaged tissue, and excision of devitalised bone fragments at a mean of six hours (three to eight) following presentation to the Emergency Department. Prophylactic antibiotic therapy (intravenous cefuroxime) was continued until a second-look procedure and closure, which was performed 48 hours after the initial debridement. The initial treatment of the fracture was dictated by the configuration of the fracture and the feasibility of obtaining satisfactory reduction and internal fixation.

**Statistical analysis.** The patients with skin compromise were compared with the remainder of the proximal humeral fracture cohort to examine potential risk factors for this form of injury, including age, gender and mechanism of injury. The Mann-Whitney U test was used for continuous data and Fisher’s exact test for categorical data. A p-value of < 0.05 defined statistical significance. We estimated the prevalence of open fractures using local population census data and person-years methodology.

**Results**

From the 7825 patients with proximal humeral fractures we identified 16 (0.2%) who had sustained local skin compromise (Table I). The overall prevalence of open proximal humeral fracture was 0.19 per 100,000 person-
years in our local population. The mean age of these patients was 56.5 years (31 to 86), with eight men and eight women. The mechanism of injury was a simple fall in eight patients, a fall from a height in four, a motor vehicle accident in three and an industrial injury in one. There were no open fractures due to penetrating trauma during the study period.

Despite the younger mean age and the greater proportion of male patients with fractures having skin compromise compared with the remainder of the proximal humeral fracture cohort (56.5 years versus 64.3 years, respectively; and 50.0% male versus 29.5% male, respectively), these differences did not reach statistical significance with the numbers available (p = 0.14 and p = 0.12, respectively). Nor were there any statistically significant differences in the mechanism of injury when patients with open fractures were compared with the remainder of the proximal humeral fracture cohort (p = 0.23).

We identified two subgroups of patients according to the extent of the initial soft-tissue injury and their fracture configuration.

**Open fractures.** In these ten patients (mean age 53.3 years (31 to 86), four males and six females) there was frank penetration of the skin overlying the fracture (Table I, patients 1 to 10). The mechanism of injury was a simple fall in two patients, a fall from a height in four patients, a road traffic accident in three and an industrial accident in one. In nine cases the skin wound was small (Gustilo and Anderson grade I or II) and localised over the anterior deltoid. At exploration there was a defect in the anterior third of the deltoid, through which the fractured proximal shaft had ‘buttonholed’ to penetrate the skin (Fig. 1a). None of these patients had evidence of brachial plexus or vascular injury. The remaining patient sustained a Gustilo and Anderson grade IIIB injury when his arm was trapped in industrial machinery, and there was a more extensive skin wound and...
Initially closed injuries with either skin tethering or delayed skin breakdown and sinus formation. In six patients (mean age 61.8 years [52 to 70], four males, two females) there was no frank open wound but there was skin compromise produced by the fracture fragments (Table I, patients 11 to 16). Once more, all six patients had displaced Neer two-part fractures of the surgical neck, five with comminution in the metaphysis and one with an undisplaced fracture of the greater tuberosity. The shaft was displaced anteriorly in all cases, and the humeral head fragment was in neutral alignment in two cases and in varus in four. The mechanism of injury was a simple fall from at or below standing height in all cases.

In two patients there was skin tethering produced by the humeral shaft at the fracture site which had displaced through the anterior third of the deltoid muscle and was lying subcutaneously (Fig. 2). These patients were treated by immediate closed manipulation under sedation to remove the pressure on the overlying skin. Open reduction and plate fixation was then performed though a lateral deltid-splitting approach to avoid the area of injury to the anterior deltid. One of these patients had a further fall two weeks after his original surgery and suffered a fracture at the tip of the plate. This was successfully treated by revision surgery to insert a longer plate.

In the other four patients there was marked bruising over the anterior deltoid, but the skin was not initially thought to be compromised. All four had severe medical comorbidities and were treated non-operatively in a collar and cuff. As the subcutaneous haematoma resolved they developed delayed skin penetration and sinus formation over the anterior deltid between two and seven weeks after injury. In two patients there was a moderate growth of *Staphylococcus aureus* from wound swabs, whereas there was no bacteriological growth on swabs from the other two patients. All patients were treated by exploration of the sinus, which extended to the fracture fragment that had penetrated the deltid muscle in all patients. The sinus tract was excised, debrided and lavaged. The bone end within the deltid was trimmed and reduced. The patients with proven infection were treated with repeated debridement, but despite this the infection proved difficult to eradicate. Both eventually developed an infected nonunion. Because of their poor medical health aggressive surgical treatment was thought to be inappropriate, and their infection was stabilised by long-term antibiotic suppression. They both had further occasional discharge from the sinus tract. The two patients with sterile sinuses both developed nonunion after the sinus tract had healed. They were both successfully treated by delayed open reduction and plate fixation at six and eight months respectively after their original injury.

**Discussion**

Our study confirms the rarity of proximal humeral fracture with skin compromise, with an incidence of 0.2% of all proximal humeral fractures. Patients with open fractures had a younger mean age and included a greater proportion of males than the general proximal humeral fracture population, although these differences did not reach statistical significance with the numbers available. To our knowledge...
there are no other previous reports of open fractures of the proximal humerus due to blunt trauma with which to compare our results. Although the management of these injuries has not previously been described, a predetermined treatment algorithm would have strengthened this study. Furthermore, prospective identification of patients with open fractures or at risk of skin compromise would also have been of benefit.

Despite these limitations, we were able to identify two subgroups of patients with open fractures, one in which there was a frank open skin penetration and the other where the fracture fragments penetrated the musculocutaneous envelope to lie subcutaneously. In the latter group, this caused skin compromise from either tethering (in two of the six cases) or delayed skin penetration with the development of a sinus (in four of the six cases). Although the skin tethering caused by the displaced shaft fragment was clinically obvious, recognition of the subcutaneous position of the shaft fragment in the other four patients with initially closed injuries was more difficult. This was due to the extensive swelling and bruising over the anterior deltoid, which masked the true extent of skin compromise. The sinuses that occurred between two and seven weeks after the injury presumably developed as a result of both resolution of the subcutaneous haematoma and continued subcutaneous irritation by the displaced shaft fragment. In future, earlier recognition of this rare pattern of injury may allow earlier treatment to be instituted before the skin penetration occurs.

Although the acute management of these two subgroups was different, it is likely that the mechanism of injury was similar, as the configuration and displacement of the fracture and the soft-tissue injury were comparable. In both groups the fracture was a relatively simple Neer two-part fracture of the surgical neck, albeit that there was marked metaphyseal comminution in 13 cases and an undisplaced fracture of the greater tuberosity in three. In all cases the shaft fracture was markedly displaced anteriorly, with no cortical contact with the humeral head, and had led to the integral compromise by penetrating through the anterior third of the deltoid muscle. It seems likely that the injury mechanism in all these cases involved an axial load and extension force. Most of the true open fractures had a high-energy mechanism of injury whereas those in which there was subcutaneous displacement were all sustained in low-energy falls. However, despite the severe injury to the soft-tissue envelope, none of our patients had evidence of a neurovascular injury, which suggests that the anterior displacement of the shaft fragment protects the medial structures in the axillary sheath from injury.

Our results indicate that open fractures in medically fit patients should be treated like other open metaphyseal fractures, with immediate debridement and lavage and open reduction and internal fixation. The marked initial fracture displacement increases the risk of nonunion if treatment is non-operative and this risk is likely to be substantially reduced by operative treatment. Our current preferred option is to use proximal humeral locking plate fixation, as this facilitates correction of the varus deformity of the humeral head, which is frequently encountered. This has been shown to reduce the risk of later fixation failure in this fracture configuration. In keeping with published guidelines for open fractures of the lower limb we continue prophylactic antibiotic therapy until soft-tissue closure or for a maximum of 72 hours, whichever is sooner. The relatively innocuous skin lesions that occur with these injuries dictate that plastic-surgical intervention is not often required. The decision as to whether to treat medically frail patients with open fractures in a similar manner is more controversial. In view of the high prevalence of nonunion in the patients treated non-operatively following open fracture, we favour a policy of early internal fixation where possible.

The most appropriate management for fractures where there is no initial frank skin penetration is less clear. Where there is skin tethering, initial closed reduction to reduce the potential for pressure necrosis is appropriate. Early open reduction and plate fixation may be indicated. Unfortunately, a substantial proportion of patients with initially closed injuries who develop delayed skin penetration and sinus formation are either medically unfit or have a history of excessive alcohol and tobacco consumption. The treatment of these patients is more challenging: early open reduction and internal fixation may be associated with a high risk of infective complications or fixation failure, whereas non-operative treatment incurs a substantial risk of symptomatic nonunion. A formal protocol of treatment for injuries in these patients is therefore difficult to formulate, although given the high rate of nonunion associated with non-operative treatment, we currently favour open reduction and internal fixation of these fractures wherever possible.

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References

