The Holstein-Lewis Humeral Shaft Fracture: Aspects of Radial Nerve Injury, Primary Treatment, and Outcome

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Objective: The primary aim was to describe the epidemiology of the Holstein-Lewis humeral shaft fracture, its association with radial nerve palsy, and the outcome regarding recovery from the radial nerve palsy and fracture healing. The secondary aim was to analyze the long-term functional outcome.

Setting: Six major hospitals in Stockholm County.

Design: Descriptive study. Retrospective assessment of radial nerve recovery and fracture healing. Prospective assessment of functional outcome.

Patients: Twenty-seven patients with a 12A1.3 humeral shaft fracture according to the OTA classification satisfying the criteria of a Holstein-Lewis fracture in a population of 358 patients with 361 traumatic humeral shaft fractures.

Intervention: Nonoperative or operative treatment according to the decision of the attending orthopaedic surgeon.

Main Outcome Measurements: Recovery of the radial nerve, fracture healing, and functional outcome according to the Short Musculoskeletal Function Assessment (SMFA).

Results: The Holstein-Lewis humeral shaft fracture constitutes 7.5% of all humeral shaft fractures and was associated with an increased risk of acute radial nerve palsy compared with other types of humeral shaft fractures, 22% versus 8% ($P < 0.05$). The fractures of 6 of the 7 operatively treated patients healed after the primary surgical procedure while 1 fracture healed after revision surgery. The fractures of all patients treated nonoperatively healed without any further intervention. All 6 radial nerve palsies (2 patients treated nonoperatively and 4 operatively) recovered. The functional outcome according to the SMFA was good with no differences between the nonoperatively and operatively treated patients: SMFA dysfunction index 7.6 and 9.7, respectively, and SMFA bother index 6.1 and 6.8, respectively.

Conclusions: The Holstein-Lewis humeral shaft fracture was associated with a significantly increased risk of acute radial nerve palsy. The overall outcome regarding fracture healing, radial nerve recovery, and function was very good regardless of the primary treatment modality, that is, operative or nonoperative treatment. The indication for primary operative intervention in this fracture type appears to be relative.

Key Words: radial neuropathy, humeral fracture, treatment outcome, quality of life

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INTRODUCTION

The Holstein-Lewis humeral shaft fracture, that is, a simple spiral fracture in the distal third of the shaft with the distal bone fragment displaced and the proximal end deviated toward the radial side, was originally described by Arthur Holstein and Gwilym Lewis in the *American Journal of Bone and Joint Surgery* in 1963.[1] They initially presented 7 cases with this fracture type associated with radial nerve palsy. In a subsequent study, 341 consecutive fractures were reviewed and 6 patients with radial nerve palsies were found, 5 of whom showed this specific fracture pattern. The authors hypothesized that the reason for this seemingly high association with radial nerve palsy was that the fracture occurs at a point where the radial nerve runs through the lateral intermuscular septum and lies in direct contact with the bone and has limited mobility. Due to the force of the injury, the distal fragment is moved proximally and radially, potentially lacerating or trapping the radial nerve. The overall conclusion drawn by the authors was that open reduction and internal fixation should be regarded as the treatment of choice for this type of injury.

In a systematic review of radial nerve palsy associated with humeral shaft fractures, Shao et al[2] found only 2 articles[3,4] presenting data on the Holstein-Lewis fracture. They concluded that the specific relationship between the Holstein-Lewis fracture and radial nerve palsy is probably not as strong as the original authors concluded.[1] The systematic review suggests that the region at risk includes both the middle and distal part of the shaft.

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This finding of Shao et al is in accord with our results from an epidemiological study including 401 humeral shaft fractures.[5] Our reported overall incidence of radial nerve palsy was 8.5%, and a logistic regression analysis showed that fracture localization both in the middle and distal part of the shaft was associated with an increased risk of developing a radial nerve palsy.

The primary aim of the present study was to describe the epidemiology of the Holstein-Lewis humeral shaft fracture, its association with radial nerve palsy, and the outcome regarding recovery of the radial nerve and fracture healing based on data from our epidemiological study. The secondary aim was to analyze the long-term functional outcome.

PATIENTS AND METHODS

All patients 16 years or older with a humeral shaft fracture admitted to any of the 6 major hospitals in the county of Stockholm (serving about 20% of the total population of Sweden) during the years 1998–1999 were reviewed, and a total of 397 patients with 401 humeral shaft fractures were found. Radiographs for all these patients were reviewed, and 361 of the fractures were found to be traumatic and classifiable according to the OTA classification system.[6,7] The epidemiology of these fractures has been reported previously.[5] Twenty-seven patients had a type 12A1.3 fracture satisfying the criteria of a Holstein-Lewis fracture, that is, a simple spiral fracture in the distal third of the shaft with its distal bone fragment displaced and with its proximal end deviated toward the radial side (Fig. 1) and with the radial nerve at risk for being injured (Fig. 2).

Data on age, gender, injury mechanism (ie, low energy or high energy), the primary treatment modality (operative or nonoperative, a decision made by the attending orthopaedic surgeon at each hospital), clinical recovery from the radial nerve palsy, and fracture healing were collected from the medical records.

All 27 patients were contacted for a follow-up at a mean of 6.3 years (2.5–8.9) after the injury. The follow-up included an assessment of range of motion (ROM) of the shoulders (flexion, extension, abduction, and rotation), elbows (flexion, extension, supination, and pronation), and wrists (flexion and extension) measured with a standard goniometer, and the results were expressed as the percentage of the uninjured arm. The abduction strength of the shoulders was tested with the Nottingham Mecmesin Myometer and the strength of the handgrip with the Jamar Hydraulic Hand Dynamometer. The results were expressed as the number of kilograms noted for the injured arm subtracted from the number of kilograms noted for the uninjured arm. Furthermore, a neurological examination of the injured arm was performed, and the sensibility was tested for light touch and a sharp pin and was categorized as normal, impaired, or hyperesthetic.

The patients were also asked to rate their current musculoskeletal functional status according to the Short Musculoskeletal Function Assessment (SMFA).[8,9] The SMFA comprises 46 items summed up in the dysfunction index and the bother index. The scores range from 0 to 100, a higher score indicating poorer function.

FIGURE 1. The Holstein-Lewis fracture, that is, a simple spiral fracture in the distal third of the shaft with its distal bone fragment displaced and with its proximal end deviated toward the radial side.

Statistical Methods

The statistical software used was SPSS 15.0 for Windows (SPSS Inc., Chicago, IL). Categorical variables were tested by the χ^2 test or Fisher exact test. Numerical variables in independent groups were tested by the Mann-Whitney U test. All tests were two-sided. The results were considered significant at $P < 0.05$. Trend values, $0.05 \geq P \leq 0.1$ are displayed; all other values are reported as not significant.

Ethical Considerations

The study was conducted according to the Helsinki Declaration,[10] and the Local Ethics Committee approved the protocol.

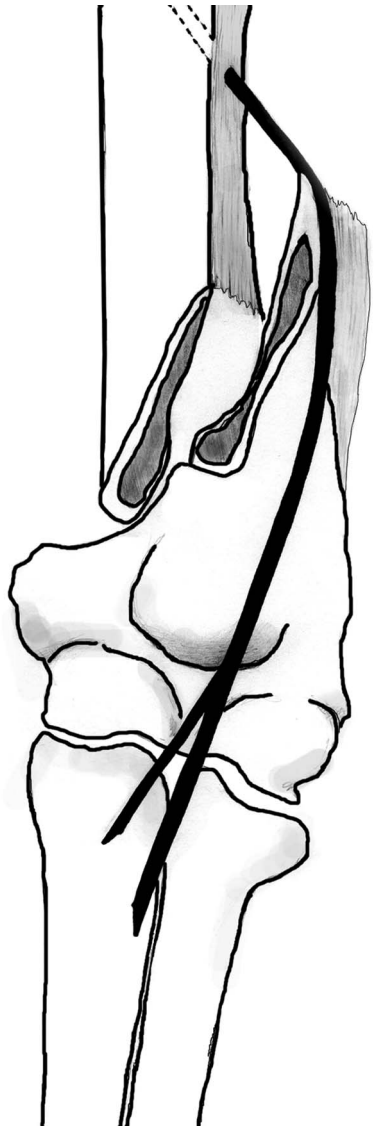

FIGURE 2. The radial nerve at risk for being injured.

RESULTS

Background Data

The background data for all 361 patients and for the 27 (7.5%) patients with a Holstein-Lewis fracture in relation to those with other types of humeral shaft fractures are displayed in Table 1. There was a trend toward patients with a Holstein-Lewis fracture being younger than the others.

All fractures were closed, and none of the patients had multiple injuries even though patients with a Holstein-Lewis fracture had sustained their fracture significantly more often after a high-energy trauma ($P < 0.05$).

The Holstein-Lewis fracture was significantly more frequently associated with radial nerve palsy, that is, in 6 of 27 patients (22%), compared with 27 of 334 patients (8%) with other fracture types ($P < 0.05$).

TABLE 1. Background Data for All Patients Included and in Relation to Fracture Type, That Is, a Holstein-Lewis Fracture Compared With Those With Other Types of Humeral Shaft Fractures

	All Patients (n = 361)	Holstein-Lewis fx (n = 27)	Other fx Types (n = 334)	*P*
		Mean (SD)		
Age, years	61.9 (21.5)	51.3 (27.7)	62.7 (20.7)	0.059
		n (%)		
Gender				
Female	219 (61)	18 (67)	201 (60)	NS
Male	142 (40)	9 (33)	133 (40)	
Injury type				
Low energy	286 (79)	17 (63)	269 (81)	<0.05
High energy	75 (21)	10 (37)	65 (19)	
Radial palsy				
Yes	33 (9)	6 (22)	27 (8)	<0.05

P values for differences between the groups. fx = fracture; NS, not significant.

Clinical Outcome

Seven of the 27 patients (26%) with a Holstein-Lewis fracture had primary surgery. The background data for all 27 patients with a Holstein-Lewis fracture and separately in relation to the treatment modality, that is, nonoperative or operative treatment, are displayed in Table 2. Patients with associated radial nerve palsy were significantly more often treated operatively ($P < 0.05$), but with regard to other baseline data, there were no differences between those treated nonoperatively and operatively.

The fractures of 6 of 7 of the operatively treated patients healed after the primary surgical procedure, which was preformed within a mean of 9 days (1–28) after the injury. The operative procedure was plating in 5 patients, antegrade nailing in 1, and lag-screw fixation in 1. One of the patients operated upon using a plate required revision surgery with plate fixation after 30 days to achieve healing. The fractures of all patients treated primarily nonoperatively healed without any further intervention.

All 6 radial nerve palsies (2 nonoperatively and 4 operatively treated patients) healed. The radial nerve in the 4 operatively treated patients was explored and found to be macroscopically intact.

Long-Term Functional Outcome

At the final follow-up at a mean of 6.3 years (2.5–8.9) after the injury, 6 patients were deceased, 1 had emigrated, 1 could not be examined due to severe mental illness, and 1 patient was not retrievable, thus leaving 18 patients (67%) for assessment (14 nonoperatively and 4 operatively treated). The SMFA was available for all 18 patients. There were no significant differences with regard to baseline data on comparing the 18 patients with follow-up data with the 9 patients lost to follow-up (data not shown).

Four patients were not accessible for physical examination due to other diseases affecting the function of the contralateral arm (eg, arthritis of the shoulder joint or fracture of the elbow joint).

TABLE 2. Background Data for All Patients With a Holstein-Lewis Fracture in Relation to the Treatment Modality, That Is, Nonoperative or Operative Treatment

	All Patients (n = 27)	Nonoperative (n = 20)	Operative (n = 7)	*P*
		Mean (SD)		
Age, years	51.3 (27.7)	52.6 (28.6)	47.6 (26.6)	NS
		n (%)		
Gender				
Female	18 (67)	15 (75)	3 (43)	NS
Male	9 (33)	5 (25)	4 (57)	
Injury type				
Low energy	17 (63)	12 (60)	5 (71)	NS
High energy	10 (37)	8 (40)	2 (29)	
Radial palsy				
Yes	6 (22)	2 (10)	4 (57)	<0.05

P values for differences between the groups. NS, not significant.

There were no significant differences between the nonoperatively and operatively treated patients with a Holstein-Lewis fracture with regard to functional outcome. The SMFA dysfunction index was 7.6 and 9.7, respectively, and the SMFA bother index 6.1 and 6.8, respectively. The ROM of the injured shoulder, elbow, and wrist was hardly affected (97%, 99%, and 99%, respectively, of the ROM of the uninjured side), and the muscular strength of the injured shoulder and hand was only slightly impaired compared with the uninjured side (data not shown). The neurological examination was normal in all patients.

DISCUSSION

The present study, based on an epidemiological study of 361 humeral shaft fractures,[5] focusing on the outcome for patients with Holstein-Lewis humeral shaft fractures, showed that this fracture type accounted for 7.5% of all the humeral shaft fractures and was associated with a significantly increased risk of acute radial nerve palsy compared with patients with other types of humeral shaft fractures, 22% versus 8%. The outcome regarding fracture healing, recovery of radial nerve function, and function was excellent regardless of the primary treatment modality, that is, operative or nonoperative.

The relatively low (7.5%) incidence of the Holstein-Lewis fracture in our study population is supported by the single previous epidemiological study on humeral shaft fractures by Tytherleigh-Strong et al[11] showing an even lower incidence of this specific fracture pattern (3.8%) probably due to the fact that pathological and peri-implant fractures were included in their analysis. Our finding that patients with a Holstein-Lewis fracture compared with patients with all other fracture types more often sustained their fracture after a high-energy trauma (37% and 19%, respectively, Table 1) indicates that this particular fracture pattern is seen more frequently in designated trauma centers. Moreover, the high rate of recovery of nerve function in our patients may be due to the fact the predominant injury mechanism in the patients with Holstein-Lewis fractures was low energy (63%).

Our results confirm the increased risk of sustaining an associated primary radial nerve palsy in this particular fracture pattern as previously reported.[1,2] However, the Holstein-Lewis fracture seems to share this increased risk for radial nerve palsy with all fractures in both the middle and distal part of the shaft.[2,5]

Despite the previous recommendations that open reduction and internal fixation should be regarded as the treatment of choice for this type of injury,[1] the majority of our patients were treated nonoperatively, although the subgroup of patients with associated radial nerve palsy were operated upon more often. Furthermore, in contrast to the report by Holstein and Lewis, none of our patients developed secondary palsy during the nonoperative treatment.

The fractures of all nonoperatively treated patients healed, and they recovered their radial nerve function. The outcome regarding radial nerve recovery was equally uneventful in the operatively treated group while 1 patient developed a nonunion that healed after revision surgery.

The long-term functional outcome according to the SMFA was generally good, and the patients with a Holstein-Lewis fracture had better (lower) SMFA scores than a reference population of patients with healed fractures without associated radial nerve palsies[12] regarding both the dysfunction index (8.1 and 20.8, respectively) and the bother index (6.3 and 18.2, respectively). The overall good SMFA results were reflected in only limited restrictions in the ROM of the injured shoulder, elbow, and wrist and the muscular strength of the injured shoulder and hand. Furthermore, there were no differences in these aspects on comparing the nonoperatively treated patients with those treated operatively.

A major strength of the study is that the Swedish personal identification number system allowed us to identify virtually all patients with humeral shaft fractures seeking treatment in the Stockholm area during the studied period of time resulting in a well-defined population. Moreover, the follow-up regarding fracture healing and radial nerve recovery was complete.

The fact that only 67% of the patients were available for the follow-up of the long-term functional outcome is a limitation of the study. However, the long follow-up time, a mean of 6.3 years, resulted in 22% of the patients being deceased. In summary, we have good reason to assume that our results are amenable to generalization in the defined population, that is, adult patients with closed Holstein-Lewis humeral shaft fractures after blunt trauma.

In conclusion, the Holstein-Lewis humeral shaft fracture was associated with a significantly increased risk of acute radial nerve palsy. The overall outcome regarding fracture healing, radial nerve recovery, and function was very good regardless of the primary treatment modality, that is, operative or nonoperative treatment. The indication for primary operative intervention in this fracture type appears to be relative.

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