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Marius M. Scarlat · Christian Cuny
Benjamin A. Goldberg · Douglas T. Harryman II
Frederick A. Matsen

The lateral impaction of the shoulder

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Abstract 17 patients had radiographic demonstration of injury to the clavicle, scapula and ribs from an impact delivered to the lateral shoulder. The study included 13 males and 4 females whose ages ranged from 18 to 83 years (average 45 years). Most injuries were sustained in falls or motor vehicle accidents. Analysis of these cases suggests a biomechanical hypothesis concerning the transmission of the impact forces within the shoulder girdle. According to this hypothesis, the impaction force applied to the lateral shoulder is transmitted from outside inward following two paths. The anterior and superior path passes through the acromio-clavicular joint, the clavicle, the costo-clavicular joint and the sterno-clavicular joint. The posterior and inferior path is transmitted within the gleno-humeral joint, the scapula and the scapulo-thoracic joint. Major impacting force is required to disrupt the anterior and posterior arches of the shoulder girdle. When both of these supporting structures are damaged, the patient is at risk for more serious injuries, including disruption of the thorax, shoulder joint, brachial plexus and neck.

Résumé Les auteurs communiquent l'observation des caractéristiques communes pour 17 cas de traumatismes complexes de l'épaule, associant comme lésions des fractures de la clavicule de l'omoplate et des côtes. L'analyse des cas suggère une hypothèse biomécanique concernant la transmission des forces d'impaction traumatique au niveau de la ceinture scapulaire. Conformément a cette hypothèse, la force traumatique appliqué sur la face externe de l'épaule est transmise de l'extérieur vers l'intérieur sur deux voies vectorielles. La voie antéro-supérieure passe par l'articulation acromio-claviculaire, la clavicule, l'articulation costo-claviculaire et l'articulation sterno-claviculaire. La voie postéro-inférieure passe par l'articulation gléno-humérale, l'omoplate et le complexe scapulo-thoracique. Théoriquement, les lésions peuvent se produire sur tout point du trajet vectoriel. En particulier, les lésions peuvent se manifester au niveau de l'arche antérieure ou postérieure du cintre omocle-thoracique, en extérieur et a l'intérieur du cintre.

C. Cuny
Orthopaedic Department, Centre Hospitalier Régional,
Hôpital Bonsecours, Metz, France

B.A. Goldberg
Orthopaedic Department, University of Illinois, Chicago, USA

D.T. Harryman II · F.A. Matsen
Orthopaedic Department, University of Washington, Seattle, USA

M.M. Scarlat (✉)
Service de Chirurgie Orthopédique et Traumatologique,
Centre Hospitalier Général, BP 82,
83407 Hyères-les-Palmiers Cédex, France
e-mail: mscarlat@ch-hyeres.fr
Tel.: +33-6-6217-9396, Fax: +33-4-9400-2735

Introduction

Trauma to the lateral aspect of the shoulder is not uncommon [5, 8, 13, 26]. Usually the force applied to the shoulder girdle is relatively mild, resulting in isolated lesions of the clavicle or of the acromion-clavicular joint. Severe high-energy blunt trauma that "laterally impacts" the shoulder is less common.

The purpose of this paper was to investigate and classify cases of combined lesions of the shoulder girdle resulting from lateral impaction and explain the mechanisms of these injuries.

Materials and methods

Seventeen patients who presented to our institution from 1995–1997 with severe blunt trauma, lateral impaction, to the shoulder that included at least two ipsilateral injuries were retrospectively reviewed (Table 1). There were 13 male and 4 female patients, ages ranging from 18 to 83 years (average 45.5 years). Plain x-rays were made in all cases at admission, with at least 3 views of the shoulder girdle and at least 2 views of the thorax (Fig. 1). Computed tomography with reconstruction was reviewed when available.

The transmission of forces that occur during injury to the shoulder was simulated using a tri-dimensional finite element

Table 1 Lateral impaction of the shoulder – series presentation

Nr Crt	Name	Age	Sex	Type acci-dent	Side	Domi-nant	Anterior Arch	Posterior Arch	Internal Lesions	External Lesions	Associated Lesions	Haemo-Pneumo-Thorax	Drain	Treatment	Hosp. Stay	Work incapa city	Follow-up (months)	Constant score (last follow-up)	Constant score (opposite side)	Sub-jective result	Deltoid Strength (1–5)	Residual features at 6 months
1	M.O.	36	M.	Moto	Right	Right	1/3 middle Clavicula	Scapular neck	Fr. 2–6 Ribs	None	Fr. ipsilat eral wrist (Colles)	Yes	No	Clavicular Osteo-synthesis	8	2	18	92	100	Exc.	4	Slight Dropping Shoulder
2	S.H.	77	M.	1m. fall	Right	Right	St.-Clav. fract.+ ant.disl.	Scapular neck + body	Fr. 3 Rib	None	None	No	No	Fig. of 8 for 3 weeks	15	Retired	8	62	82	Good	4	Excellent Subjective Result
3	P.M.	48	M.	6m. fall	Left	Right	1/3 middle Clavicula	Scapular neck	Fr. 2–8 Ribs	None	Subtro-chanteric chanteric Ipsilateral Fr.	No	No	Clavicular Osteo-synthesis	28	4	8	92	100	Exc.	5	Slight Discomfort for Sport Act
4	L.J-P	41	M.	Scooter	Left	Right	1/3 middle Clavicula	Scapular body	Fr. 2–3 Ribs	None	None	No	No	Clavicular Osteo-synthesis	3 3	4	92	100	Exc.	5		Excellent Subj. Result
5	P.D.	62	F.	Fall (car)	Right	Right	AC sprain	Scapular neck	Fr. 2–5 Ribs	GH ant. Disloca-tion	(Colles) Supra-condylar	Yes	No	Toraco brachial sling 3 weeks	35	Retired	14	63	87	Fair	3	AC arthrosis (arthro-scopic tr)
6	V.C.	73	M.	Moto	Right	Right	1/3 middle Clavicula	Scapula + Glenoid	Fr. 3–8 Ribs	None	None	Yes	No	Fig. of 8 for 3 weeks	12	Retired	9	75	85	Good	4	Excellent Subj. Result
7	L.L.	83	F.	Fall (car)	Left	Right	1/3 Undis placed mid. Clav.	Scapular body	Fr. 3–9 Ribs	None	None	No	No	Toraco-brachial sling 3 weeks	8	Retired	9	60	72	Good	3	Excellent Subj. Result
8	C.P.	49	M.	3m fall	Right	Right	1/3 middle Clavicula	Scapular neck + body	Fr. 1–4 Ribs	None	None	Yes	No	Clavicular Osteo-synthesis	5	3	7	85	98	Good	4	Ipsilateral secondary mild Thoracic Outlet Syndrome
9	C.S.	18	M.	Moto	Right	Right	1/3 middle Clavicula	Scapular body	Fr. 2–6 Ribs	Humeral Neck Fr	Ipsilateral femur, ankle, patella	Yes	Yes	Fig. of 8 for 3 weeks	32	4	12	100	100	Exc.	5	Excellent Subj.+ Objective Result
10	K.N.	25	M.	Moto	Right	Right	Bi-focal Clavicula	Scapulo-Th. Disl.	Fr. 2–5 Ribs, Upper Plexus Subclav. Vein Injury	None	Fr. Ipsi-lateral Femur	Yes	Yes	Emergency Vascular Surgery, 8 days ICU for respira-tory care, No fixation of the shoulder girdle	30	Invalid	14	0	98	Poor	0	Final Invalidity and major handicap
11	P.J-P	42	M.	Moto	Left	Right	1/3 middle Clavicula	Scapular neck	Fr. 2–5 Ribs	None	Fr. Ipsi-lateral wrist (Colles)	Yes	Yes	Fig. of 8 for 3 weeks	7	2	10	96	100	Exc.	4	Excellent Subj. Result
12	A.Y.	67	F.	Car	Right	Right	1/3 middle Clavicula	Scapular body	Fr. 2–6 Ribs	None	Cervical Sprain	No	No	Toraco-brachial sling 3 weeks	8	Retired	10	68	86	Good	3	Good Sub-jective Result
13	Y.F.	32	M.	3m fall	Right	Right	1/3 middle Clavicula	Scapular body	Fr. 2–4 Ribs	None	None	No	No	Fig. of 8 for 3 weeks	6	2	8	84	96	Good	4	Good Sub-jective Result

Table 1 (continued)

Nr Crt	Name	Age	Sex	Type accident	Side	Dominant	Anterior Arch	Posterior Arch	Internal Lesions	External Lesions	Associated Lesions	Haemo-Pneumo-Thorax	Drain	Treatment	Hosp. Stay	Work incapacity	Follow-up (months)	Constant score (last follow-up)	Constant score (opposite side)	Subjective result	Deltoid Strength (1–5)	Residual features at 6 months
14	H.R.	25	M.	Moto	Left	Right	AC dislocation (stage III)	Scapular neck + body	Fr. 2–4 Ribs	None	Ipsilateral sacro-iliac separation with Acetabular fracture	Yes	Yes	Sling + AC strapping; surgery for the associated lesions; 5 days ICU for respiratory assistance	30	3	9	92	100	Exc.	5	Stage III residual AC separation External clavicular resection, CAL transfert to the clavicular and coraco-clavicular screw fixation
15	F.C.	26	F.	Moto	Left	Right	1/3 Undisplaced mid Clav.	Scapular body	Fr. 2–6 Ribs	Severe burn of the deltoid region	Cervical Sprain	No	No	Toraco-brachial sling 3 weeks	35	2	7	96	92	Exc.	5	Excellent Subj.+ Objective Result
16	M.R.	42	M.	Car	Left	Right	Internal 1/3 Clavicula	Scapular neck Coracoid fracture	Fr. 1–9 Ribs	None	None	Yes	No	Toraco-brachial sling 3 weeks	12	2	2.5	36	88	Poor	1	Axillary Nerve Paralysis
17	S.F.	28	M.	Moto	Right	Left	1/3 middle Clavicula	Scapular neck	Fr. 2–4 Ribs	None	None	No	No	Fig. of 8 for 3 weeks	4	2	2	–	1	–	–	–

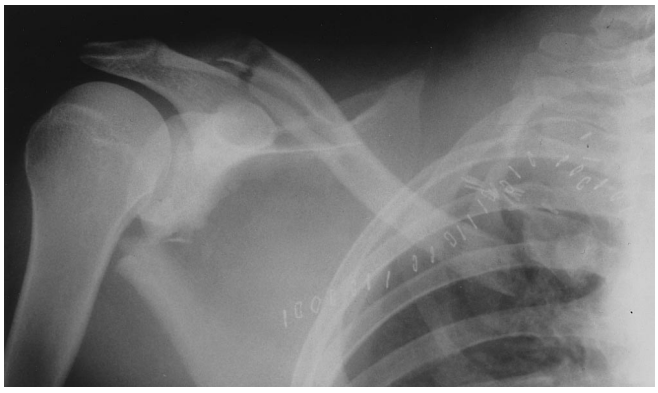

Fig. 1 Mid-shaft clavicle, scapular body and multiple rib fractures after an 8 m fall with landing on the tip of the shoulder. Hemopneumothorax developed 24 h after admission, requiring thoracic drain and ICU respiratory surveillance. Coexisting fracture of the ipsilateral femur

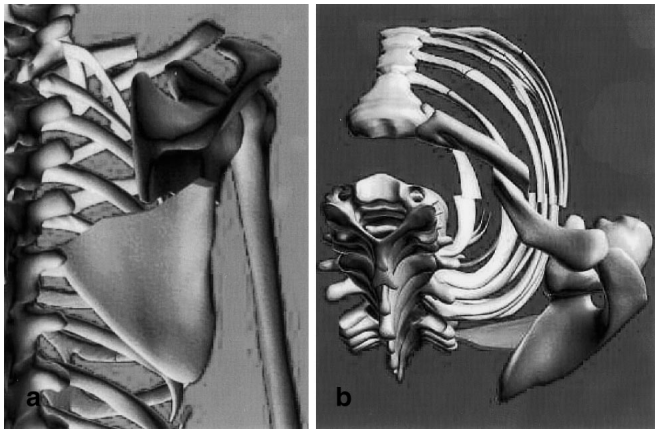

Fig. 2a,b A severe lateral impaction injury as shown by the 3-dimensional computer model

analysis model. The model was created with 3Dstudio Max® (KINETIX, San Francisco, CA 94107) running on a desktop workstation. All of the injured structures were noted and placed on the three-dimensional model of the chest, scapula, and upper limb. The scapula and upper limb were modeled using an anterior and posterior arch (Fig. 2). The anterior arch of the shoulder girdle was defined as including the acromioclavicular joint, the clavicle, the sternoclavicular and the costoclavicular joints. The posterior arch of the shoulder girdle was defined as including the glenohumeral joint, the Scapula and the scapulothoracic joint.

The anterior and the posterior arches of the shoulder girdle are connected by the Superior Shoulder Suspensory Complex (SSSC). The SSSC is defined as the ring composed of the glenoid process, the coracoid, the coracoclavicular (CC) ligaments, the distal clavicle, the acromioclavicular (AC) joint and the acromion [10].

"External lesions" were defined as an injury that was superficial to the shoulder girdle, such as humeral head fractures, glenohumeral dislocations, and soft-tissues trauma of the external border of the shoulder (i.e. deltoid muscle, axilary nerve, skin and subcutaneous tissues). In addition, "internal lesions" were defined as an injury located deep to the shoulder girdle such and included rib and thoracic trauma, mediastinal, vascular, and neurologic injuries.

The transmission of a medially directed virtual lateral impaction force (LIF) on the external aspect of the shoulder was studied by applying a vector analysis (Fig. 3). The LIF divides into

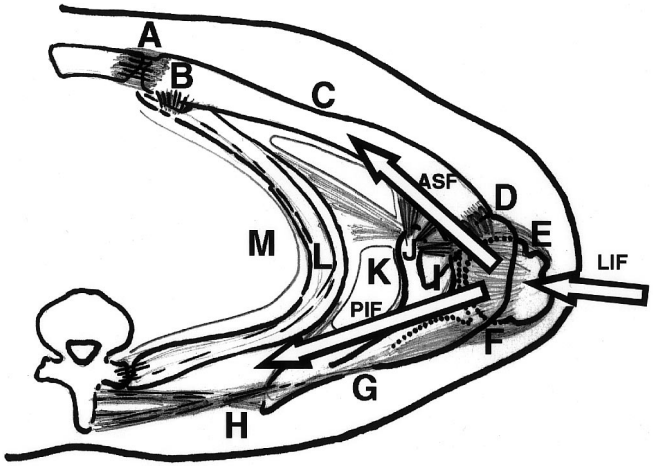

Fig. 3 Biomechanic hypothesis: distribution of the lateral impaction force (*LIF*) within the anterior and posterior arches of the shoulder girdle (superior view). Possible involved structures on the anterior and posterior arches of the shoulder girdle: sterno-clavicular joint (*A*), costo-clavicular ligament (*B*), *Clavicle* (*C*), acromio-clavicular joint (*D*), proximal humerus (*E*), gleno-humeral joint (*F*), acromion and scapular spine (*G*), scapulo-thoracic joint (*H*), scapula (*I*), coracoid process and attached ligaments (*J*), brachial plexus and vessels (*K*), thoracic cage (*L*), pleuro-pulmonary and mediastinal structures (*M*)

two resultant vectors – the Antero-Superior Force (ASF), and the Postero-Inferior Force (PIF). The ASF is transmitted through the anterior arch and the PIF through the posterior arch of the shoulder girdle. Shoulder function was clinically assessed at follow-up using the Constant score [7] and a self-assessment questionnaire that was developed by the authors. The result was considered excellent when the shoulder function allowed full range of motion, pain-free activities and when the Constant score was higher than 80% compared to the opposite side. A good result was defined when the range of motion was complete, but with occasional pain, and with a Constant score between 60 and 80% compared to the opposite side. The result was considered fair when the shoulder was painful most of the time but allowing everyday activities, with a score less than 60% as compared to the opposite side and poor when the shoulder and/or the upper limb function was compromised by a neurological injury.

A self-assessment questionnaire was completed by the patients at the 6 months follow-up visit or by mail. This questionnaire assessed the ability to perform activities of the everyday living (comb the hair, brushing teeth, personal hygiene, lift 2 and 10 kg, overhead activities possible or not), the level of pain on a 1–10 visual analog scale, and the ability to sleep comfortably. The patients rated also their global result as "excellent, good, fair and poor" on a subjective basis. A radiological evaluation at follow-up was also completed.

Results

Fifteen patients were able to describe the mechanism of injury as a fall on the lateral aspect of the shoulder. There were 9 falls from a 2-wheel vehicle (8 motorcycle and 1 scooter), 2 motor vehicle accidents with direct side-sweeping and 2 auto-pedestrian accidents. There were 4 falls from heights varying between 1 and 6 meters. The dominant shoulder was injured in 9 cases (9 right-handed patients) and the non-dominant shoulder was injured in 6 cases (5 right handed persons and 1 left-handed). There were 3 cases

Table 2 Series mentioning complex fractures of the shoulder girdle

Authors	Year	Purpose of study	Total number of cases	Complex ipsilateral fractures
1. Ada and Miller	1989	Scapular fractures	113	25%
2. Epraheim et al.	1986	Scapulo-thoracic dislocation	15	100%
3. Findlay	1937	Scapular fractures	39	Not precise (unknown)
4. Hardegger	1984	Scapular fractures	37	Not precise (unknown)
5. Herscovici et al.	1992	Floating shoulder	9	100%
6. Leung et al.	1993	Ipsilateral scapula and clavicle	15	100%
7. McGahan	1980	Scapular fractures	121	47%
8. McGinnis et al.	1989	Scapular fractures	39	92%
9. McGinnis and Denton	1989	Scapular fractures	40	26% clavicle, 51% ribs
10. Nordqvist and Petterson	1992	Scapular fractures	72	25%
11. Ramos et al.	1997	Ipsilateral scapula and clavicle	16	100%
12. Rikkli et al.	1995	Unstable shoulder girdle	12	100%
13. Sommellet et Féry	1978	Omo-Cleido-Thoracic syndr.	12	100%
14. Thompson et al.	1985	Scapular fractures	58	54%
15. Williams et al.	1999	Floating shoulder	15	100%

with associated fractures of the ipsilateral superior limb, that required osteosynthesis.

All patients had at least one lesion of the anterior arch of the shoulder girdle and one lesion of the posterior arch of the shoulder girdle. In addition, all patients had isolated or multiple rib fractures. Other lesions were seen in the neighboring regions of the shoulder girdle in 4 cases .

Five patients had polytrauma that included 4 femoral fractures. Three patients required ICU admission for associated cranial trauma (1 case) or for respiratory assistance following massive haemo-pneumothorax and pulmonary contusion (2 cases). Cervical sprains were noted in 2 cases. The treatment for the lesions of the shoulder girdle was non-surgical in 13 cases and surgical in 4 cases. Surgery was performed when the shoulder girdle was shortened by more than 20 mm. Surgery was not performed when concomitant skin or soft tissue lesions might jeopardize the surgical result. Surgery consisted of fixation of the clavicle only and was achieved using a Dynamic Compression Plate in three cases and one Kirschner 2.0 wire in one case.

At six months of follow-up, all patients declared themselves stable in terms of shoulder function. One patient was lost at follow-up but the other 16 were assessed clinically and radiologically. Eleven patients had a good or excellent subjective and objective result. Two patients had neurologic lesions leading to final functional losses. These patients with neurologic injuries had surgery and had poor results. Surgical indications included a complete brachial plexus palsy and an axillary nerve palsy. One patient developed thoracic outlet syndrome. Two patients had residual AC joint pathology requiring treatment (one transfer of the Coraco-Acromial Ligament with distal clavicular resection for residual stage III AC separation and one AC joint arthroscopic debridement for secondary arthritis).

The computer-generated model noted that internal structures were damaged only if both the anterior and the posterior arches of the shoulder girdle were disrupted.

Discussion

Complex shoulder trauma is not uncommon. Non-operative treatment has been recommended in most cases [2, 28]. Some recommend clavicular osteosynthesis as the only stabilizing procedure [8, 11, 12, 22], while others advocate osteosynthesis of both clavicular and scapular fractures [17]. The treatment of lesions that are assessed separately (i.e. clavicular fracture, scapular neck fracture, GH dislocation) may not be the same as for the injuries when they are assessed together.

Goss [10] and Williams (personal communication) believe that the stability of the shoulder girdle depends on the integrity of the superior shoulder suspensory complex (SSSC). The SSSC is defined as the ring composed of the glenoid process, the coracoid, the coracoclavicular (CC) ligaments, the distal clavicle, the AC joint and the acromion. Williams and colleagues recommend non-surgical treatment for all ipsilateral clavicle and scapula fractures if the suspensory complex is intact and if the shoulder girdle is not medially displaced by more than 20 mm. Williams noted that not all combined fractures of the clavicle and of the scapular neck result in the clinical appearance of a floating shoulder, but only those associating lesions of the AC and CA ligaments. However, the SSSC model does not explain all associated injuries (e.g. such as chest, ribs, nerve) that occur secondary to high energy blunt shoulder trauma.

Shoulder girdle anatomic discontinuity has been assessed separately from the accompanying thoracic trauma, glenohumeral dislocations or proximal humeral fractures [1, 14, 15, 18, 20]. Stanley et al. explained the mechanism of clavicular fracture as due to blunt shoulder trauma [26]. This fits in with our hypothesis on lateral impaction forces and in fact may be an early stage of lateral impaction injury. Scapular fractures have been associated with rib and clavicular fractures, pleuro-pulmonary lesions, extremity fractures, cervical sprains, and craniocerebral trauma [4, 21, 27]. The same associations are noted in publications on scapulothoracic (ST) dislocations [3, 6, 9, 16, 19, 23]. These studies note that an associated fracture of the ipsilateral clavicle and/or rib occurs between 20 and 51% of the time (Table 2).

To our knowledge, a biomechanical approach for the combined lesions of the shoulder girdle was first made by Sommelet et. al. They noted the association of clavic-

ular, scapular and ribs fractures and called them "Syndrôme Omo-Cle-Thoracique". The authors demonstrated that this association is pathognomonic for lesions produced by lateral impaction and recommended stabilization of the clavicle as unique procedure for treatment in order to restore length of the shoulder girdle [24, 25].

Associated injuries from lateral impaction forces depend on the *direction* of the initial force (antero-external, postero-external, descending or ascending), the *magnitude* of this force, and on the *compliance* of the soft tissues at the point of impact. The tissues in proximity to the initial application area of the LIF will obviously absorb the energy of impact, sometimes resulting in severe lesions of the skin, subcutaneous tissues, deltoid muscle, of the lateral edge of the acromion or/and of vascular and neurologic elements of the area.

The lateral impaction mechanism can explain the occurrence of both simple and complex lesions of the shoulder girdle. Less severe trauma directed anteriorly may affect only the AC joint or clavicle. Posteriorly directed trauma may involve only the scapular spine, glenoid, or acromion. Severe lateral impaction which disrupts both anterior and posterior arches may result cause internal lesions such as bracial plexus, ribs, or pleura.

The anatomical lesions that are injured following a lateral impaction injury to the shoulder are various and may be misdiagnosed. There is need to define clearly the possible lesions following such an injury. If both arches of the shoulder girdle are disrupted, the surgeon should look for internal and external lesions. The most common internal lesion in our series were rib fractures, but there were also pneumothoracies, brachial plexus injuries and major vessels disruptions.

The final outcome of a lateral impaction injury of the shoulder is depending on the so-called "associated lesions". Out of the 17 cases in this series, only 2 cases had a poor outcome, and these cases had concommitant neurological lesions.

To our knowledge, all previous studies concerning this specific type of trauma resulting in floating, dropping or unstable shoulder girdle discuss the co-existent features like ribs fractures or pneumothoracies as "associated lesions". If we consider the lateral impaction hypothesis as correct, the possible lesions are not "associated", but "co-existent". They occur as a result of the same mechanism and they should be evaluated and treated following a well-defined logarithm.

Both the anterior and the posterior arches of the shoulder girdle support the gleno-humeral joint. The disruption of both arches can possibly result in lesions of this joint.

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