

**Shoulder impairment following critical illness: a prospective cohort  
study**

**Running Title:** Shoulder impairment following critical illness

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**Supplemental Digital Content**

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**Supplemental Table 1: Comorbidities**

<b>Comorbidity</b>	<b>No. Patients</b>
COPD	19
HTN	31
Diabetes	12
OA	8
IA	5
IHD	4
CKD	5
Asthma	10

*Note:* COPD= Chronic obstructive pulmonary disease, HTN= Hypertension, OA= Osteoarthritis, IA= Inflammatory arthritis, IHD= Ischaemic heart disease, CKD= Chronic kidney disease

**Supplemental Table 2: Risk Factors Analysed for Developing Shoulder Impairment**

Variable	No. (%) of patients* N= 96
Mechanical Ventilation	72 (74)
Days, median (IR)	3 (7)
NMBA	
Infusion	10 (10)
Bolus	31 (32)
Infection	
Present	40 (42)
Presumed	50 (52)
None	6 (6)
CVC	84 (88)
Vascath	13 (14)
RRT	11 (11)
Patient Position	
Usual	90 (94)
Other	6 (6)
MRC SS†, median (IR)	48 (27)
Rehabilitation Undertaken	89 (93)
Day Commenced, median (IR)	5 (6)
ICD	7 (7)
Tracheostomy	11 (12)
Thoracotomy	2 (2)
Hard Collar	3 (3)

Note: IR= Interquartile Range, NMBA= Neuromuscular Blocking Agents, CVC= Central Venous Catheter, RRT= Renal Replacement Therapy, MRC SS= Medical Research Council Sum Score, ICD= Intercostal Drain.

\*Unless stated otherwise

†n= 68

## **Definition of ICU-Related Shoulder Impairment**

A threshold of moderate pain on movement was included in our definition of shoulder impairment to rule out participants with transient low-level pain. The range of movement (ROM) parameters were chosen based on documented values for both the impaired and non-impaired shoulder [1-4]. The Constant-Murley Score (CMS) is one of the most commonly used outcome measures aimed at evaluating shoulder function [5]. A CMS of less than 80 was included as the lowest reported mean scores for individuals without shoulder impairment is 81, which is in females over the age of 70 [6, 7].

The QuickDASH is a commonly used measure of upper limb function [5, 8]. The threshold of 40 was chosen for severe upper limb dysfunction as this has been shown to be equivalent to a shoulder dislocation or upper limb fracture and associated with an inability to work [9].

## **Shoulder Assessments**

Patients underwent the all shoulder assessments by one of two experienced ICU physiotherapists. Shoulder ROM was measured in a standardised position using a standardised set of instructions and the CMS strength assessment was completed in a standardised position.

## ROM Assessment Instructions

1. Flexion: movement of the arms forward in front of the body.

The patient is sitting for the physical examination. Ideally have the patient's feet on the floor as standard. The patient should be sitting back in the chair so any trunk movement is minimised and the position is standardised. Ask the patient to raise both arms together, measuring on side at a time (see instruction below).

Demonstrate the movements once yourself, before you give the verbal instruction.

The measurements should be taken with a goniometer from the side of the body with the centre of the goniometer positioned in the centre of the deltoid muscle bulk.

*“Move both arms forwards and overhead as far as you can without pain”*



2. Abduction: the movement of arms out to the side, in line with the body

The patient is sitting for the physical examination. Ideally have the patient's feet on the floor as standard. The patient should be sitting back in the chair so any trunk movement is minimised and the position is standardised. Ask the patient to raise both arms together, measuring on side at a time (see instruction below).

Demonstrate the movements once yourself, before you give the verbal instruction.

The measurements should be taken with a goniometer from behind the patient with the centre of the goniometer positioned in the posterior body of deltoid. The patient should be sitting nearer the painful side of the chair to allow the goniometer to be next to the body.

*“Move both arms out to the side as high as you can without pain”*



### 3. Lateral Rotation: rotation away from the centre of the body

The patient is sitting for the physical examination. Ideally have the patient's feet on the floor as standard. The patient should have their elbow at their side with their hand pointed straight ahead and their elbow flexed to 90°. Ask the patient to externally rotate the hand as far as possible with the elbow held against the trunk (see instruction below). Demonstrate the movements once yourself, before you give the verbal instruction. The measurements should be taken with a goniometer from in front of the patient with the centre of the goniometer on the olecranon process of the ulna. The stationary arm should remain at a right angle to the patient while the moveable arm should move parallel with to the longitudinal axis of the ulna pointing towards the styloid process.

*“Keep your elbows at your side and rotate your forearm outwards as far as you can without pain”*





## CMS Strength Assessment Procedure

Patient is in sitting with arm at 90° abduction in scapular plane (30° forward from the body), holding the 'Balanza™', palm facing the floor. Examiner stands on the belt so that it is taut & directly under the patient's hand.

*'Pull up in the air against the belt and maintain the pull as much as you can without pain. Keep it there until you hear the beep.'*



**Supplemental Table 3:** Summary of shoulder imaging reports

<b>Patient</b>	<b>Modality</b>	<b>Report</b>
1	USS	Subacromial bursitis
2	X-ray	Bilateral superior subluxation
3	USS	Supraspinatus tendinosis, subacromial bursal thickening
4	MRI	Supraspinatus tear, bursitis, posterior subluxation of humeral head
5	X-ray	Mild calcification tendonitis
6	X-ray	Unreported
7	USS	Bursitis, supraspinatus tendinopathy, biceps tenosynovitis

Note: USS= ultrasound scan, MRI= Magnetic Resonance Imaging

**Supplemental Table 4:** Results of the Univariate Analysis Included in the Multivariate Analysis

Categorical variables	Shoulder Dysfunction		No Shoulder Dysfunction		p value	OR (95% CI)
	n	%	n	%		
Infection	71	97	19	83	0.028*	7.6 (1.3-44.5)
Tracheostomy	11	15	0	0	0.061	**
NMBA Infusion	10	14	0	0	0.111	**
HTN	28	38	3	13	0.039*	4.3 (1.2-15.8)
Diabetes	12	16	0	0	0.064	**
Continuous and ordinal variables	Median <sup>†</sup>	IR <sup>†</sup>	Median <sup>†</sup>	IR <sup>†</sup>	p value	
Age	66	24.3	57	27	0.008*	
MRC SS	48	32	52	12	0.042	
APACHE II, mean and SD	19.7	6.6	16.8	5.4	0.062	

Note: NMBA= Neuromuscular Blocking Agents, HTN= Hypertension, MRC SS= Medical Research Council Sum Score, APACHE= Acute Physiology and Chronic Health Evaluation

†Unless stated otherwise

\*significant at  $p < 0.05$

\*\*OR not calculable due to zero counts

**Supplemental Table 5: Variables Not Included in the Multivariate Analysis**

	<b>Shoulder Impairment n= 73</b>		<b>No Shoulder Impairment n= 23</b>		<b>p value</b>
	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	
<b>Categorical variables</b>					
Male	41	56	13	57	0.98
Female	32	43	10	43	0.98
Emergency admission	70	96	22	96	1.0
Readmission	7	9	0	0	0.19
Shoulder dysfunction	10	14	3	13	1.0
Neck dysfunction	8	11	1	4	0.68
Ventilation	55	74	17	74	0.96
NMBA	27	36	8	35	0.88
NMBA Bolus	24	32	7	30	0.85
CVC	65	89	19	83	0.47
Vascath	9	12	4	17	0.73
RRT	8	11	3	13	1.0
Patient position	4	5	2	9	0.62
Rehab undertaken	68	93	21	91	0.66
ICD	7	9	0	0	0.19
Thoracotomy	2	3	0	0	1.0
Hard collar	3	4	0	0	1.0
COPD	16	22	3	13	0.54
OA	6	8	2	9	1.0
Inflam Arth	5	7	0	0	0.33
IHD	4	5	0	0	0.57
CKD	3	4	2	9	0.58
Asthma	9	12	1	4	0.44
<b>Continuous and ordinal variables</b>	<b>Median</b>	<b>IR</b>	<b>Median</b>	<b>IR</b>	<b>p value</b>
ICU LOS	9	7	8	7	0.70
Hospital LOS	25	32.2	28	27	0.64
Days ventilated	3	8	3	5	0.58
RRT Hours	0	0	0	0	0.85
Days to commence rehab	4	6	5	6	0.90

*Note:* NMBA= Neuromuscular Blocking Agents, CVC= Central Venous Catheter, RRT= Renal Replacement Therapy, ICD= Intercostal Drain, COPD= Chronic Obstructive Pulmonary Disease, OA= Osteoarthritis, Inflam Arth= Inflammatory Arthritis, CKD= Chronic Kidney Disease, LOS= Length of Stay.

**Supplemental Table 6: Results of the Multivariate Analysis**

<b>Risk factor</b>	<b>p value</b>	<b>Adjusted OR (95% CI)</b>
Infection	0.998	-
Tracheostomy	0.999	-
NMBA Infusion	0.999	-
HTN	0.063	7.96 (0.90 – 70.7)
Diabetes	0.998	-
Age	0.392	1.02 (0.98 – 1.07)
MRC SS	0.640	0.99 (0.93 – 1.04)
APACHE II severity score	0.577	1.03 (0.92 – 1.12)

*Note:* NMBA= Neuromuscular Blocking Agents, HTN= Hypertension, MRC SS= Medical Research Council Sum Score, APACHE= Acute Physiology and Chronic Health Evaluation

## References

1. Donatelli RA. Functional anatomy and mechanics. In: Physical Therapy of the Shoulder (Fifth Edition). Elsevier; 2012. p. 9-23.
2. Robinson C, Seah KM, Chee Y, Hindle P, Murray I. Frozen shoulder. Journal of Bone & Joint Surgery, British Volume. 2012;94(1):1-9.
3. Constant C, Murley A. A clinical method of functional assessment of the shoulder. Clin Orthop. 1987;214:160-4.
4. Hayes K, Walton JR, Szomor ZL, Murrell GA. Reliability of five methods for assessing shoulder range of motion. Australian Journal of Physiotherapy. 2001;47(4):289-94
5. Rocourt MH, Radlinger L, Kalberer F, Sanavi S, Schmid NS, Leunig M, et al. Evaluation of intratester and intertester reliability of the Constant-Murley shoulder assessment. Journal of shoulder and elbow surgery. 2008;17(2):364-9.
6. Katolik LI, Romeo AA, Cole BJ, Verma NN, Hayden JK, Bach BR. Normalization of the Constant score. Journal of shoulder and elbow surgery. 2005;14(3):279-85.
7. Yian EH, Ramappa AJ, Arneberg O, Gerber C. The Constant score in normal shoulders. Journal of shoulder and elbow surgery. 2005;14(2):128-33.
8. Kolber MJ, Salamh PA, Hanney WJ, Samuel Cheng M. Clinimetric evaluation of the disabilities of the arm, shoulder, and hand (DASH) and Quick DASH questionnaires for patients with shoulder disorders. Physical Therapy Reviews. 2014;19(3):163-73.

9. Angst F, Schwyzer H, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: disabilities of the arm, shoulder, and hand questionnaire (DASH) and its short version (QuickDASH), shoulder pain and disability index (SPADI), American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, Constant (Murley) score (CS), simple shoulder test (SST), Oxford shoulder score (OSS), shoulder disability questionnaire (SDQ), and Western Ontario shoulder instability index (WOSI). *Arthritis care & research*. 2011;63(S11).