Alterations in Functional Movement After Axillary Burn Scar Contracture: A Motion Analysis Study

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Children with axillary burns often develop scar contractures that restrict shoulder movement. Objective data on functional movement patterns after contracture formation is sparse. The purpose of this study was to determine how axillary contractures affect shoulder movement during activities of daily living (ADLs). This was a prospective study of children with axillary contractures scheduled for surgical release. Three-dimensional upper extremity kinematic analysis was used to assess shoulder, elbow, and trunk motion during two ADLs: high reach and hand to back pocket. Results were compared with a pool of 49 normal age-matched controls. Eleven children with axillary contractures were compared with controls. During high reach, significant decreases in shoulder flexion, shoulder internal rotation, arm pronation, and trunk extension occurred. Elbow flexion increased significantly. In the hand to back pocket task, shoulder extension and elbow flexion decreased and shoulder abduction increased. Axillary contractures result in quantifiable movement changes during ADLs. Aggressive rehabilitation is required to prevent contracture formation. Three-dimensional motion analysis is a unique tool for the quantification of functional limitations and provides an objective method to evaluate treatment efficacy in patients with axillary contractures. (J Burn Care Rehabil 2003;24:104–108)

Each year, over 2.5 million people seek medical assistance for acute burn injuries, and approximately 100,000 are hospitalized, including a large number of children.[1] The yearly direct and indirect costs of burn injury are enormous. The average cost of hospital care for a patient with burns ranges from $29,560 to $117,506; this figure rises significantly for patients with extensive burns.[2] A large proportion of these costs can be directly attributed to the management of burn scars.

Children in particular are subject to the development of severe burn scar contractures. Normal growth, graft loss or shrinkage, and inadequate therapy can combine to result in the development of significant burn scar contractures. These contractures can lead to restriction of extremity movement, particularly over major joints, such as the axilla and knee. Contracture release is performed to restore "normal" range of motion in burned extremities. A review of more than 3000 survivors of burn injury revealed that approximately 20% of patients require some type of reconstructive procedure.[3] Although numerous studies assess the appearance of postburn scar contracture release, the immediate and long-term effects of contracture release on extremity function have received little attention.[4–9]

The current standard for assessing the severity of burn scar contractures involves measuring the passive and active range of motion of an extremity in a single plane. Although this provides clinicians with valuable data, these measurements do not give information on functional motion or how the extremity moves during activities of daily living (ADLs), such as bathing, dressing, or toileting. A patient with a significant axillary contracture may not be able to raise an arm above his or her head but may still able to comb his or her hair by using different maneuvers. Objective characterization of changes in extremity kinematics, or how an extremity compensates to perform functional tasks, is needed to define the goals of reconstructive surgery.

Three-dimensional motion analysis, which involves the calculation of extremity motion relative to anatomic

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reference planes, is frequently performed in ambulatory children to assess gait. It has less frequently been used to evaluate upper extremity function.[10–12] Motion analysis is a noninvasive, quick, and painless technique that allows the documentation of baseline extremity motion during functional activities. Because of the recent development of clinical applications of upper extremity motion analysis, the requirement for specialized equipment, and need for user expertise, this technology has not been previously used to evaluate burn scar contractures. Three-dimensional motion analysis has the potential to provide objective, reproducible data on the functional outcomes of children with upper-extremity contractures.

The purpose of the study was to document the changes in movement of the shoulder, elbow, and trunk during ADLs after the formation of axillary burn scar contractures using three-dimensional motion analysis and to compare these movement patterns with those of normal children. The hypothesis of the study was that children with burn contractures develop compensatory movement patterns to accomplish activities of daily living.

MATERIALS AND METHODS

The study was a single-center, prospective, nonrandomized study. Children aged 5 to 18 years with planned axillary burn scar contracture release from January 1, 2001, to January 1, 2002, at Shriners Hospitals for Children Northern California were eligible for the study. The study was approved by the University of California Davis Institutional Review Board. After we obtained informed consent, children underwent kinematic testing in the Motion Analysis Lab within 1 week of operative intervention. Children were excluded if they had a fracture of the extremity within the past year, a known neurologic deficit in the involved limb, or could not cooperate with the study. To minimize variables associated with data collection for all motion testing, the children were compared with normal children tested under the same circumstances using the same equipment. The upper extremity kinematic analysis was performed using a method previously developed and described by our motion analysis laboratory.[10]

For upper-extremity analysis, kinematic data were assessed using two designated activities of daily living: high reach (simulating reaching for an object on a shelf) and hand to back pocket (simulating toileting). Participants in the high reach maneuver were instructed to raise their hand to touch an imaginary object as high above their head to maximal height in the sagittal plane. In the hand to back pocket task, children were asked to reach behind their back to touch the buttock with the palm (if possible). As such, each motion did not evaluate maximal joint excursion that could be achieved but did measure the joint excursion used to accomplish the given task.

Eighteen retroreflective markers (1 inch in diameter) were placed over prominent bony landmarks of the upper extremity. The 18 marker positions included: head top, left head, right head, C-7, sternal notch, bilateral shoulders, bilateral elbows, bilateral ulnar and radial wrists, bilateral hands, bilateral anterior superior iliac spines, and the midpoint of the posterior superior iliac spines. Children repeated the movement with computer tracking to assure task completion and consistency of data collection. Kinematic data were collected at 60 Hz using the ExpertVision System® hardware and software (Motion Analysis Corporation, Santa Rosa, CA). Two-dimensional marker position data for each of the eight cameras were combined and processed with the ExpertVision Software to obtain three-dimensional coordinates for each of the retroreflective markers. Marker position data were used to generate segment orientations and joint locations for use in the upper-extremity biomechanical model.[10]

The biomechanical model consists of 10 segments (head, neck, shoulder girdle, upper arms, lower arms, hands, pelvis) whose local coordinate systems were used to calculate upper-extremity motion relative to anatomic reference planes. Each segment was defined by a proximal and distal point located at a joint center and a third noncolinear point for rotational orientation. Base (zero) position was defined as the anatomic position. This was a standardized position with the subject standing, arms extended at the side, with forearms fully supinated and palms forward. All joints were assumed to have fixed centers of rotation.

Motion patterns were recorded bilaterally for each patient. Movements were compared with a previously collected pool of controls obtained in the same laboratory using the same equipment. The joint position at the extreme of desired movement was recorded to allow data comparison with normal measurements. Thus, we collected data that reflected the movement strategy to achieve an activity as well as the position of the limb at the point of achievement. Mean maximal extremity joint excursions at the position of task completion (ie, when the hand was overhead and when the hand was at the back pocket) were used for data comparison using a Student's *t*-test with $P < .05$ considered significant. Data were expressed as the mean ± SD. Positive values represent joint flexion, abduction, pronation, or external rotation. Negative values represent joint extension, adduction, supination, or internal rotation

RESULTS

Eleven children with axillary burn scar contractures scheduled for release were analyzed. Mean age at the time of analysis was 8.4 years (range, 6 to 13 years), and mean total body surface area burned in the initial injury was 37%. All children had both anterior and posterior axillary contracture banding. Seven of the children had bilateral axillary contractures. The remaining four children had unilateral contractures; thus, the motion patterns of a total of 18 axillae were analyzed. Three patients had concomitant trunk burns, and two had elbow contractures. No significant differences in shoulder or trunk motion were seen between patients with multiple contractures and those with purely axillary contractures. Movement patterns were compared with 49 normal controls, a total of 98 axillae, obtained in the same lab. Motion analysis documented several alterations in patient movement patterns during functional tasks as a result of burn scar contracture formation. Before release (Table 1), children demonstrated significant loss during high reach of shoulder flexion (average loss of 65 degrees), shoulder internal rotation (average loss of 14 degrees), compensatory trunk extension (average loss of 14 degrees), and forearm pronation (average loss of 24 degrees) with an increase in elbow flexion (average increase of 28 degrees). Shoulder abduction was not affected, and the pattern of motion paralleled normal movement (Figure 1). Elbow movement patterns were also different (Figure 2). In the hand to back pocket task (simulating movements needed for toileting), a decrease in shoulder extension (average loss of 13 degrees) and an increase in shoulder abduction (average increase of 7 degrees) occurred (Table 1). Elbow flexion was also significantly decreased an average of 14 degrees.

DISCUSSION

The current treatment of axillary burn scar contractures is based on evaluation of the patient's active and passive range of motion in a single plane. To date, the objective assessment of motion during functional tasks has been limited because of the lack of an established method for measuring movement patterns. However, range of motion data per se do not provide information on how or whether a patient can perform activities of daily living. Motion analysis, by simulating movements used to perform ADLs, gives further information on how a child with an axillary contracture may accomplish a given ADL. A child could potentially have a severe contracture that does not limit his or her ability to perform ADLs; conversely, a child may have a relatively small contracture that may be very disabling. Identifying movement patterns after contracture formation represents the an important step in the assessment of functional outcomes for children with axillary burn scar contractures. Three-dimensional motion analysis, as demonstrated by this study, has the potential to fill this void. It provides objective, reproducible data that can be used for the assessment of these children.

This study used three-dimensional motion analysis to study two activities of daily living: raising the hand above the head and reaching for the back pocket. As such, they are NOT measures of the extent to which the upper extremity and shoulder can move; they are a measure of the extent of motion used to accomplish the required task. Maximal joint excursion during performance of these tasks differs from normal ana-

Table 1. Motion in degrees with SD in parentheses during three-dimensional motion analysis of high reach and hand to back pocket maneuvers

	High Reach		Hand to Back Pocket	
	Axillary Contracture	Control	Axillary Contracture	Control
Shoulder flexion	69 (50)*	134 (28)	−37 (13)*	−50 (8)
Shoulder abduction	35 (14)	32 (12)	11 (10)*	4 (8)
Shoulder external rotation	−6 (36)*	−20 (19)	−30 (39)	−30 (13)
Elbow flexion	51 (24)	23 (10)	52 (20)*	66 (19)
Arm pronation	36 (27)	60 (45)	−45 (68)	−68 (52)
Trunk flexion	−9 (28)*	−23 (24)	14 (15)	11 (11)

Positive values represent joint flexion, abduction, pronation, or external rotation. Negative values represent joint extension, adduction, supination, or internal rotation.
* $P < .05$ by Student's *t*-test.

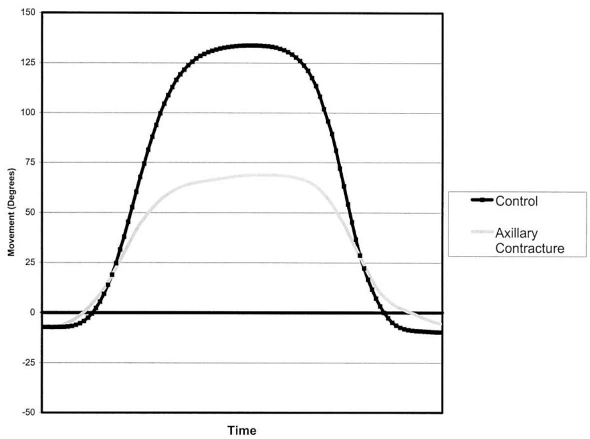

Figure 1. Mean shoulder joint flexion for controls vs all patients with axillary scar contracture during the high reach maneuver.

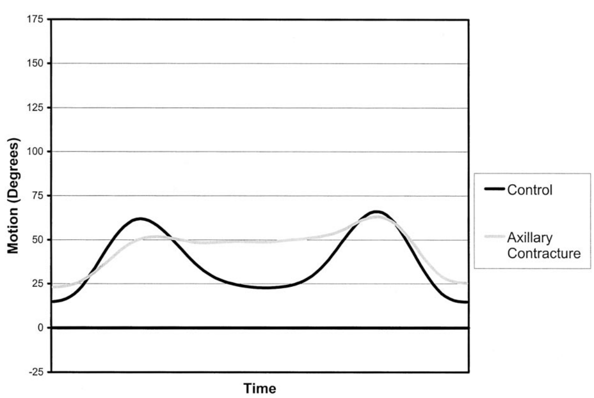

Figure 2. Mean elbow joint excursion for controls vs all patients with axillary contractures during the high reach maneuver.

tomic shoulder range. It is expected that maximal joint excursion during these activities would be less than what can be accomplished by passive range of motion evaluation aimed at determining the extremes for extent of joint movement. As a rule, the accomplishment of ADLs does not require maximal joint excursion, and patients use the minimal excursion necessary to accomplish a task.

Axillary contractures do indeed result in marked movement changes during functional tasks. As expected, children with axillary contractures had decreased shoulder flexion and internal rotation during the high reach maneuver. To complete the high reach task, they increased elbow flexion to raise the hand above the head. The decrease in internal rotation is also a compensatory response used by the patient to augment the shoulder flexion, which has been impaired by the contracture. That shoulder flexion remains impaired despite these maneuvers is further confirmation of the severity of the motion limitations generated by the axillary contracture. Both elbow flexion and trunk extension would result in the elevation of the hand independently of shoulder motion. These compensatory motions may be one of many reasons why many children develop recurrent neck or elbow flexion contractures in conjunction with their axillary contracture. If the child cannot raise the hand above the head, he or she will lower the head to reach the target. In addition, after axillary contracture formation, trunk movement unexpectedly became "stiff," appearing to be linked to shoulder movement, which resulted in decreased trunk extension during high reach. In the hand to back pocket task, a decrease in shoulder extension led to increased shoulder abduction to move the hand away from the body before placing it behind the back. The decrease in forearm supination to contact the buttock occurs as a result of the increased strength required to supinate the arm against gravity during abduction.

In addition, the pattern of movement during the activity for children with axillary contractures differs from normal controls during the high reach task. During high reach, which involves movement primarily in the sagittal plane, normal controls display a "double-bump" pattern representing increasing flexion at the elbow at the beginning of the motion followed by near full extension at the moment the task is achieved. Flexion of the elbow occurs as the arm is brought back to start position (Figure 2). In contrast, children with axillary contractures begin the motion with a greater degree of elbow flexion and slightly increase the elbow flexion at the moment the task is achieved. This increase in elbow flexion may represent the patient's attempt to increase the hand "height" to compensate for limited shoulder flexion (Figure 2). In other words, the children are able to flex the shoulder in the sagittal plane to a limited extent (because of their axillary contracture). When the elbow is flexed with the shoulder partially flexed, the hand is elevated above the elbow, increasing the height of their reach. We have previously reported a similar compensatory movement pattern in patients with shoulder movement limitations from other causes.[13]

Although the study documents clear movement changes after contracture formation, it has several limitations. The model used for kinematic analysis has been validated, but to date no universal standard for upper extremity motion analysis exists. We used a database of normal controls obtained in our laboratory using the same equipment to minimize variability in data collection. The population tested may also have been somewhat heterogeneous. Although all patients had contractures severe enough to be scheduled for operative intervention, the potential exists for variability in the severity and location of the scar. The presence of other burn scars may also affect movement patterns. However, similar movement patterns were identified among all of the patients with axillary burn scar contractures.

CONCLUSIONS

The long-term outcome of patients with burn scar contractures continues to be the focus of many studies. The determination of the optimal timing and most effective procedure for contracture release after burn injury is limited by the lack of baseline data on function after burn scar contracture formation. This study thus represents an important step in defining functional outcomes after contracture formation. Three-dimensional motion analysis is an important tool for the quantification of functional limitations that provides an objective method to evaluate treatment efficacy in patients with axillary contractures.

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