Posttraumatic Elbow Stiffness
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CHAPTER 11

I. Discussion & Summary
II. Discussie & Samenvatting
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General Discussion & Summary

Elbow motion is essential for many daily tasks and activities. Unfortunately, stiffness remains a common sequel of elbow trauma. In this thesis, several aspects relating to posttraumatic elbow stiffness are addressed. The general aims are to review our current knowledge on posttraumatic elbow stiffness in Part I, to identify factors contributing to better results of treatment of complex elbow fracture-dislocations in Part II, to better understand the complex relationship between stiffness and disability in Part III, and to identify factors that may help improve nonoperative, operative, and postoperative treatment of posttraumatic elbow stiffness in Part IV.

Part I Current Issues

In chapter 2, a review of the literature on posttraumatic elbow stiffness is presented. Posttraumatic stiffness can be the result of articular damage and incongruity, soft tissue contracture, heterotopic ossification and nonunion. Intra-articular elbow pathology is often complicated by contracture of the joint capsule, collateral ligaments, and muscles. The thickening of the capsuloligamentous structures and the loss of soft tissue compliance are believed to result from bleeding, edema, granulation tissue formation, and ultimately fibrosis. Our understanding of the pathophysiological pathways resulting in capsular fibrosis and formation of heterotopic bone is limited. Heterotopic ossification is common after elbow trauma although it only restricts motion in a small percentage. Heterotopic bone that restricts motion is often considered a challenging problem. NSAIDs are frequently recommended as a prophylaxis against the formation of heterotopic bone based on data from the hip, but there are no controlled data regarding their use in the elbow. Given the concern of impaired bone healing, some authors therefore discourage use of NSAIDs after elbow trauma. Likewise, low-dose irradiation is another commonly recommended preventive measure that deserves more investigation. Although the risk of radiation-induced osteosarcoma seems negligible, its benefit on formation of heterotopic bone formation around the elbow has not been confirmed in prospective clinical research.

Time and exercises and/or an adjunctive splinting program restore motion to most elbows after trauma. Recently, research efforts have been aimed at the role of botulinum toxin A (Botox®) in the prevention of elbow stiffness. Some investigators believe that injection with botulinum toxin A during surgical treatment of elbow trauma or elbow stiffness (causing a transient muscle weakness for 6 to 12 weeks) may increase the range of motion that can be achieved during rehabilitation. However, there are no data supporting the effectiveness of this treatment to date, and publication of the results should be awaited.

If nonoperative management fails to restore sufficient motion, an operative contracture release can often successfully restore motion to the stiff elbow. The popularity of arthroscopic
release has increased over the past decade. Its safety is still being studied though and open release is usually advised for more complex contractures. Using an open approach, heterotopic bone can be excised with satisfactory results, although it is technically challenging. The timing of heterotopic bone resection has been controversial and used to be delayed much longer than most surgeons now recommend, i.e. as soon as the bone is radiographically mature (usually after approximately three to four months). Resection of proximal radioulnar synostosis and total bony ankylosis has traditionally been approached with trepidation, although recent data suggest that patients with bony ankylosis recover as much motion as patients with more limited heterotopic bone.

The role of continuous passive motion after operative contracture release is unclear and based on two small case series. This topic is addressed in chapter 10. Splinting may help restore elbow function if patients plateau in motion after injury or operative contracture release, and is the subject of chapter 7.

In case of severe damage to the elbow joint, a total elbow arthroplasty may be considered. However, this procedure entails serious postoperative limitations and is restricted to the less active and older patient if no other options are available. In the younger and more active patient, an interposition arthroplasty may be preferred, withstanding functional demands. Interposition arthroplasty results in pain relief and improved elbow motion in the majority of patients, but sometimes at the expense of elbow stability.

Part II Elbow Trauma

In chapter 3, we record short-term and long-term results of anterior and posterior olecranon fracture-dislocations. The average flexion arc improves significantly from an average 106 degrees at the one year follow-up to 122 degrees at an average 18 years after surgery. The results are durable over time in spite of arthritis in the majority (70%) of patients. Although a minority of patients has some degree of stiffness, most elbows function well, reflected by a satisfactory patient-rated outcome with an average DASH score of 9 points. In contrast to a previous paper, there is no difference between results of treatment of anterior vs. posterior fracture-dislocations.

The small number of studied subjects does not allow definitive conclusions on factors that are thought to be of importance for a satisfactory result. In line with previous series, poor results are associated with failure to address the coronoid process (resulting in inadequate restoration of the ulnotrochlear notch), heterotopic bone formation, or plate failure. Thus, adequate anatomic restoration of the ulnotrochlear notch including repair or reconstruction of the coronoid process seems important, as well as the use of plates of adequate strength or thickness, such as dynamic compression plates. Furthermore, pain, ulnar neuropathy and flexion arc are important predictors of outcome. Outcome is apparently affected by both
stiffness and pain. Interestingly, among 7 patients (35%) with signs of ulnar neuropathy, only two patients brought this problem to the physician’s attention.

In chapter 4, we study another complex elbow fracture-dislocation: the terrible triad pattern of injury consisting of fractures of the radial head and coronoid process, and posterior dislocation of the elbow (causing avulsion of the capsuloligamentous structures including the lateral collateral ligament). We make a comparison between patients that are treated within two weeks from the injury (“acute cohort”) with patients that are treated three weeks or more from the injury because of persistent or recurrent dislocation or subluxation after inadequate initial treatment (“subacute cohort”). All patients are treated according to a protocol addressing each component of the injury, including addition of a hinged external fixator and selective coronoid reconstruction in the subacute cohort. Patients that have acute treatment achieve significantly better flexion and extension than patients that have later treatment. The few previous series that were published on terrible triad injuries did not compare acute vs. subacute treatment. Our results with acute treatment are in line with those reported by Pugh and McKee using a comparable protocol (average flexion and extension arc of 119 degrees in our study vs. 112 degrees in their study). A more recent series by Zeiders and Patel on 32 patients that were treated using a slightly different protocol, documented an average flexion and extension deficit of 26 degrees. In their study, the medial collateral ligament (MCL) was repaired in 14 patients. Given the stable elbows in our current and previous series, we believe that repair of the MCL is not necessary to ensure stability, providing that radiocapitellar contact is restored (offering a constraint to valgus instability).

Based on our results, recovery of motion seems to be optimal with a prompt and adequate intervention. Evidence is mounting that best results are achieved when each of the three components of the terrible triad fracture-dislocation are treated (the radial head, the coronoid process, and the lateral collateral ligament): elbow stability is ensured, thereby limiting the potential for diminished function, arthrosis and stiffness on the long term. However, the most important finding in this study may be that patients that present with persistent instability or subluxation in the “subacute setting” did reasonably well: treatment addressing all components of the pattern plus additional hinged external fixation results in stable elbows, most with 85 or more degrees of flexion and extension. However, as Papandrea and Morrey suggested, early subacute treatment may yield better results than late subacute treatment.

In line with the study presented in chapter 3, we find a relatively high rate of arthrosis among patients with terrible triad fractures (17 of 32 patients; 53%)—compared to 39% in the series by Pugh and McKee. In chapter 3, we demonstrate that patients improve between the one year and longer term follow-up in spite of arthrosis in the majority of patients. No longer term
follow-up studies have been published on terrible triad injuries and it is unknown if arthrosis affects elbow motion on the long term in these patients. It would make sense that severe osteochondral changes impede smooth motion at the articular surface and thus contribute to stiffness. However, most patients in our studies have mild arthrosis and, based on the long-term results in chapter 3, we hypothesize that less severe degrees of arthrosis do not interfere with motion.

The importance of the coronoid process is increasingly recognized, largely based on research acknowledging its role as an important elbow stabilizer. In addition, the study presented in chapter 4 stresses the need for early recognition of terrible triad fractures. On radiographs, coronoid fractures may easily be missed or confused with a fracture fragment of the radial head. The use of three-dimensional computed tomography (3D-CT) is often recommended by elbow surgeons as they believe that 3D-CT would help to better appreciate complex elbow fracture-dislocations. However, this assumption was never confirmed in clinical research. In chapter 5, we investigate the effect of three-dimensional computed tomography reconstructions on the interobserver reliability in classification, fracture characteristics, and treatment decisions about coronoid fractures. The web-based setup facilitates a large international study in which 37 observers from different parts of the world participate, thereby increasing the generalizability and validity of the results. Although 3D-CT seems to improve the agreement among surgeons to some degree, the overall reliability is limited. We feel that this may be inherent to the relative infrequency of the type of injury, the scarce literature on this topic, the limited experience of surgeons with these injuries, differences in training and practice, and the lack of consensus on best management among surgeons treating these injuries.

In a second analysis, intra-observer reliability is tested by comparing the surgeon’s answer based on 2D-CT to the answer based on 3D-CT and found to be fair to moderate for the majority of questions. Previous investigations into imaging of distal humerus and distal radius fractures demonstrated the beneficial effect of 3D-CT when compared to 2D-CT on intra-observer reliability. In our study, making a slightly different comparison, intra-observer reliability is lower. This would suggest that surgeons change their opinion on classification, presence of important fracture characteristics, and treatment based on the imaging modality used.

Although the agreement among different surgeons does not improve too much, 3D-CT may help the surgeon to better appreciate a fracture and thereby facilitate planning of treatment. Three-dimensional CT improves interobserver reliability in recognition of some important fracture characteristics. Based on the results of the intra-observer and interobserver analysis in this study, we hypothesize that 3D-CT could influence treatment and outcomes. We would recommend ordering 3D-CT reconstructions in the case of complex elbow fractures and
fracture-dislocations. After all, as described in chapter 4, stiffness might be prevented when the fracture type is recognized and treated promptly.

**Part III  Stiffness and Disability**

In chapter 6, we investigate the relationship between objective physical impairment and subjective perceived disability at the level of specific tasks. Consistent with previous research we find pain to be the most important predictor of upper extremity disability. Pain even is a better predictor of perceived stiffness than the actual stiffness itself (i.e. the objective physical impairment). However, motion turns out to be the best predictor at the level of specific tasks. Apparently, subjective factors such as pain have a greater influence when disability is measured with respect to the entire arm rather than with respect to the specific anatomic site involved. Less specific measures of disability are more easily influenced by factors other than objective physical impairment.

A substantial proportion of the variability in disability cannot be explained by objective physical impairment or pain. Disability measures such as the DASH seem to measure something beyond and independent of a patient’s objective physical impairment. Such discrepancies have been described in other fields of medicine as well. There are several factors that may account for these discrepancies. For instance, secondary gain issues may affect reported pain and disability. Furthermore, we believe that a considerable part of this may be attributed to other psychosocial factors. There is a large body of literature that consistently finds strong associations between the perception of pain, the perception of disability, and psychosocial factors. For instance, coping mechanisms and depression influence the degree to which a variety of symptoms are perceived as disabling or painful.

Taking the above into account, one might argue that there is room for improvement in treatment outcome independent of the objective physical result alone. We would recommend that psychosocial influences on illness behavior be considered in the care of individual patients. Future research should be aimed at the implementation and evaluation of such treatment concepts in clinical practice.

**Part IV  Treatment**

In chapter 7, we compare static progressive vs. dynamic splints for the treatment of posttraumatic stiffness, either after treatment of the original trauma or after subsequent surgery for contracture release. There is no difference in terms of improvement in motion or disability between the two types of splints after six and twelve months of splint use. Although we instruct patients to use the splints according to the respective wearing protocol, we do not check compliance with the protocols as we want to test the effect of both splints in normal clinical practice rather than in the ideal study setting. O’Driscoll and others suggested that the continuous force of dynamic splints would lead to more discomfort and pain than a stress-
relaxation force, potentially inducing non-compliance.\textsuperscript{11} Based upon our data, the choice between splints may best be left to patients and their physicians and therapists.

None of the patients that start splinting after the initial trauma needs subsequent surgery for a capsular contracture alone, implying that splinting can successfully stretch the elbow capsule to achieve functional motion, either with a continuous or a static stress relaxation force. Thus we would conclude that, in absence of heterotopic bone, ulnar nerve compression, or nonunion blocking motion, splinting can prevent additional surgery.

In chapter 8, we undertake a retrospective comparison of the results of operative elbow contracture release in patients with and without heterotopic ossification blocking motion.\textsuperscript{81} Perhaps given the relative infrequency of heterotopic bone that restricts motion and the complexity of the surgical technique, heterotopic ossification was traditionally approached with caution and pessimism.\textsuperscript{82} This trepidation may have been based on the modest results of operative contracture release in patients with bridging heterotopic bone. For instance, after an average follow-up of 40 months, Failla et al. reported an average loss of 66 of the 121 degrees of rotation that was achieved intra-operatively\textsuperscript{83}, and Vince and colleagues documented recurrence of the resected bony bridge in two of three cases\textsuperscript{84}. However, in our study, the null hypothesis is rejected: the result of elbow contracture release actually turns out to be better when heterotopic bone is excised. We can only speculate on factors explaining this. First, it is our observation that there is limited capsular contracture in patients with heterotopic bone: thus, when the bony block is excised the problem may “simply” be resolved. Secondly, patients with capsular contracture without heterotopic bone may have other factors contributing to stiffness, such as articular incongruity or malalignment, ulnar nerve compression, a tendency to excessive scarring, or perhaps misinterpretation or overinterpretation of pain signals or a measure of depression that limit the effectiveness of the exercise program, or some combination of these factors. These factors may be less easily addressed. However, future studies should first confirm the role of each of these speculative contributors.

In the prospective study on the outcome of operative contracture release, presented in chapter 9, we find significant improvements in health status and disability after operative elbow contracture release. Stiffness can be improved in the vast majority of patients with an average gain in the flexion and extension arc of 55 degrees as compared to averages between 21 and 66 degrees in the literature, where the latter study\textsuperscript{85} included patients with extrinsic contractures only.\textsuperscript{2} However, despite the significant improvements in all outcome measures, improvement in motion does not correlate with improved health status or decreased disability. Thus, none of the disability and health status measures is sensitive to changes in motion. To our knowledge, no previous studies have evaluated the association between motion and health
status after elbow contracture release. However, the limited associations between impairment with both disability and health status in our study are in line with the results of a previous meta-analysis of studies reporting on impairment, disability and health status: in that analysis, an average 36% of disability scores and 13% of health status scores is explained by impairment.\textsuperscript{74} The lack of correlation between objective improvement and patient-rated outcome brings into question the traditional surgeon and patient focus on motion as the most important measure of success.

However, the outcome measures are sensitive to other factors: pain in particular turns out to be an important predictor of disability and health status. Pain explains between 19% and 48% of the variability in health status and disability scores. These findings are in line with our findings in chapter 6.\textsuperscript{72} The relationship between disability and impairment is complex and counter-intuitive. Impairment is a poor predictor of disability. Given the strong associations between psychosocial factors and the perception of pain, disability and health status, as reported in previous studies\textsuperscript{76-80, 86-88}, the current study again emphasizes the need for appreciation of the influence of psychosocial aspects of illness on disability and the outcomes of treatment.

While pain is the strongest predictor of health status and disability, distal humeral fracture, ulnar nerve dysfunction, and a high number of surgeries prior to the release are among the most important objective predictors and associated with worse outcome. There is a lack of evidence and consensus on the management of ulnar nerve during surgical treatment of elbow stiffness.\textsuperscript{89} The situation may be complicated by pre-existent ulnar neuropathy or entrapment of the nerve in heterotopic bone. Furthermore, with restoration of flexion after surgery, the nerve is put at risk because of the increased traction. Several authors\textsuperscript{33, 90-92} recommend release or transposition in elbows with fewer than 90 to 100 degrees of flexion and in patients with preoperative ulnar neuropathy. Based upon our data, the benefit of transposition or release of the ulnar nerve may be considered questionable in patients without pre-operative complaints. However, our study is not designed to answer questions on ulnar nerve management and we cannot make any definitive conclusions or recommendations.

In chapter 10, we study the use of continuous passive motion after operative contracture release.\textsuperscript{93} Although the study has limited power and shortcomings inherent to the retrospective nature of the study, there is no difference in improvement in motion and final motion between patients treated with or without CPM. These findings are in contrast with the two previous retrospective studies that addressed the effect of CPM after elbow contracture release.\textsuperscript{49, 50} However, these studies had some important limitations that, in our opinion, question the validity of their results. Most importantly, in the first study, patients in the CPM cohort had a more extensive release than patients that did not use CPM. In addition, patients that did not use CPM were not mobilized until ten days after surgery. In the other study, patients that used
CPM had much stiffer elbows than patients that did not use CPM (an average 21 degrees). In general, the average improvement of 59 degrees in both of our study cohorts compares favorably to the results reported in each of their studies (average improvements of 47 and 45 degrees with CPM, and 25 and 26 degrees without CPM).

As described previously, the loss of soft tissue compliance and thickening of the capsule is thought to result from bleeding, edema, granulation tissue formation, and subsequent fibrosis. The rationale behind CPM is that it would facilitate exercising during the painful immediate postoperative period, thereby minimizing fluid accumulation (blood and edema) that would later be replaced by granulation and fibrotic tissue. In an experimental study on rabbit knees, it was demonstrated that hemarthrosis can be driven away from the joint and the periarticular structures using CPM. One might argue that this effect could as well be achieved with standard postoperative exercises without CPM. Although it may be tempting to advocate CPM based on an attractive theory and support by animal research, the decision to use the device should be based on consistent clinical evidence. Both for knee stiffness as for elbow stiffness results are inconsistent. It would seem that the promotion of CPM goes beyond the data. Given the additional costs, as well as risks (e.g. wound complications or necrosis of skin flaps associated with use of the device, we would therefore discourage CPM after operative contracture release. In our opinion, postoperative management with early active and gravity assisted exercises, and eventually static progressive or dynamic splinting for residual stiffness, is indicated after operative elbow contracture release.

Finally, as reported in chapters 6 and 9: the importance of psychosocial aspects is increasingly recognized. It is conceivable that psychological aspects of rehabilitation such as self-efficacy, mindfulness, and confidence with painful post-release stretching exercises would be associated with a better arc of flexion and extension. We speculate that passive and unproven treatments like CPM may even turn out to be counter-productive. Making a patient believe and trust in a treatment that has no proven benefit might result in frustration and undermine the patient’s self-confidence.

Conclusions
In this thesis, several aspects of posttraumatic elbow stiffness are discussed. With respect to treatment of complex elbow fractures, we particularly emphasize the importance of adequate repair or reconstruction of the coronoid fracture. Three-dimensional CT reconstructions are useful in the evaluation of coronoid fractures and other types of complex elbow fractures and fracture-dislocations.

Furthermore, we discuss the discrepancy between objective impairment and subjective perceived disability and general health status, which may be the result of psychosocial factors. This discrepancy means that there is room for improvement in outcome, independent of the
objective and physical result alone. Future research should be aimed at the implementation of new treatment concepts addressing psychosocial and other factors in our current practice. We report several interesting findings regarding the treatment of elbow stiffness. Using a dynamic or static progressive splinting program, the stiffened elbow capsule can be successfully stretched in patients that do not improve in motion with standard exercises and physical therapy after elbow trauma or elbow contracture release. A splinting program can prevent additional surgery, unless joint motion is compromised by e.g. nonunion, malunion, ulnar neuropathy or heterotopic ossification. An operative contracture release results in greater improvement in motion in patients with heterotopic bone blocking motion as compared to patients without heterotopic bone. Finally, there is no role for continuous passive motion in the postoperative management following an elbow contracture release. As a result of a better understanding of complex elbow fractures, modern imaging techniques and the introduction of sometimes challenging but relatively safe surgical procedures for release of complex elbow contractures, posttraumatic elbow stiffness can be prevented or treated in the majority of patients.