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Clinical and patient-reported outcomes after anterior cervical decompression and fusion surgery

A focus on functioning and daily life

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Clinical and patient-reported outcomes after anterior cervical decompression and fusion surgery - A focus on functioning and daily life

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To Jacob, Isaac and Salah

CONTENTS

ABSTRACT	1
LIST OF PAPERS	3
ABBREVIATIONS & DEFINITIONS	4
INTRODUCTION	5
BACKGROUND	7
Anatomy and biomechanical function of the cervical spine	7
Degenerative disc disease and cervical radiculopathy	8
Management of cervical degenerative disc disease.....	10
<i>Conservative treatment</i>	10
<i>Surgical treatment</i>	10
<i>Postoperative rehabilitation</i>	12
Outcomes of ACDF surgery	12
Aspects of evaluating outcome after cervical spine surgery	13
<i>Evaluating functioning</i>	13
<i>Perspectives on evaluating surgical outcome</i>	14
Rationale of the thesis	16
AIMS OF THE THESIS.....	17
General aim.....	17
Specific aims.....	17
METHODS	19
Design	19
Inclusion	20
Participants	23
<i>Study A</i>	23
<i>Study B</i>	23
<i>Study C</i>	24
Ethical considerations	24
Interventions	25

<i>Surgical and rehabilitation treatments for participants in study A and Study B.....</i>	<i>25</i>
<i>Surgical and rehabilitation treatments for participants in Study C.....</i>	<i>25</i>
Data collection	26
<i>Patient-reported outcome measures.....</i>	<i>26</i>
<i>Data collected at previous follow-ups.....</i>	<i>29</i>
<i>Clinical measures of physical function</i>	<i>30</i>
<i>Qualitative research interview</i>	<i>33</i>
Analysis	35
<i>Statistical methods.....</i>	<i>35</i>
<i>Determining impairments.....</i>	<i>35</i>
<i>Sample size</i>	<i>36</i>
<i>Qualitative analysis.....</i>	<i>36</i>
<i>Trustworthiness in qualitative research.....</i>	<i>37</i>
RESULTS	39
Quantitative findings	39
<i>Comparisons between surgical procedures at the 10-year or more follow-up (paper I and III)</i>	<i>39</i>
<i>Factors predicting a successful long-term outcome after ACDF surgery (paper II)</i>	<i>42</i>
<i>Patient-reported differences between sub-groups based on outcome success in neck-related pain and disability (paper II).....</i>	<i>42</i>
<i>Gender differences (paper II).....</i>	<i>43</i>
<i>Evaluation of physical impairments at 11-14 years after ACDF surgery (paper III).....</i>	<i>43</i>
Qualitative findings (paper IV)	45
DISCUSSION.....	49
Main findings.....	49
Discussion of the results	50
<i>Comparisons between treatment groups</i>	<i>50</i>
<i>Follow-up over time</i>	<i>50</i>
<i>Predicting long-term outcomes</i>	<i>51</i>
<i>Gender differences</i>	<i>52</i>

<i>Physical impairments at 10-year follow up</i>	52
<i>Women's experiences of daily life</i>	54
Methodological discussion	56
<i>Quantitative methodology</i>	56
<i>Qualitative methodology</i>	58
<i>Limitations</i>	58
CLINICAL IMPLICATIONS	60
CONCLUSIONS	61
FUTURE RESEARCH.....	62
SUMMARY IN SWEDISH	63
ACKNOWLEDGEMENTS	65
REFERENCES	67

ABSTRACT

Anterior cervical decompression and fusion (ACDF), with or without an intervertebral cage to add support to the fused segment, is an established surgical treatment of cervical radiculopathy due to cervical disc disease. High recovery rates and pain reductions after surgery have been reported, with similar results with or without a cage. A few small studies have evaluated neck-related physical function and patient-reported disability with less promising results. No previous studies have evaluated clinical and patient-reported measures of functioning or compared the Cloward Procedure with the Cervical Intervertebral Fusion Cage (CIFC) more than 10 year after surgery. No studies have explored the patients' perspective on surgical outcome. Knowledge on long-term functioning may provide a base for improved postoperative care and rehabilitation. Combining the perspectives of clinicians and patients may provide a better understanding of outcome after ACDF surgery than has previously been reported.

The overall aim of the thesis was to evaluate long-term functioning after anterior cervical decompression and fusion surgery due to cervical disc disease, and to provide new insights into patients' experiences of daily life after surgery.

The more than 10-year patient-reported outcomes of pain, disability and psychosocial factors (n=77), as well as clinical outcomes of neck-related physical function (n=51) were evaluated and compared between the Cloward Procedure and the CIFC. Preoperative and surgery-related factors of importance for a successful outcome in neck-related pain and disability at 10-year follow-up were also identified. Fourteen women were interviewed at 1.5 to 3 years after ACDF to explore their experiences of daily life.

There were no differences between the surgical techniques in long-term neck-related pain or patient-reported disability. Secondary outcomes were, with a few exceptions, similar between groups. Neck-related pain decreased after surgery and remained improved from the 2-year to the 10-year follow-up. However, disability ratings remained improved only in the CIFC group. Predictors of a successful outcome in neck-related pain intensity were high preoperative neck-related pain intensity (Odds Ratio 1.06) and non-smoking (Odds Ratio 3.03). Male gender was the only predictive factor of a successful outcome in neck-related disability (Odds Ratio 4.33). Moderate to severe pain and patient-reported disability were seen in half of the participants at the 10-year follow-up, and neck-related physical impairments were seen in between 18% (cervical flexion) and 82% (neck-muscle endurance) of participants. Daily life was experienced as recovered or improved by women after ACDF surgery. However they were at the same time affected and

limited by remaining symptoms. Behaviors and activities were altered to adjust to the symptoms. Social support provided by family, social and occupational networks, and by healthcare professionals were experienced as important in a good daily life.

In conclusion: long-term pain, physical function and patient-reported disability were similar between the two ACDF techniques. High preoperative pain intensity, non-smoking and male gender predicted a successful long-term outcome. Individuals after ACDF surgery experienced improvements in pain intensity and a good perceived effect of surgery although they simultaneously reported residual or recurrent disability.

LIST OF PAPERS

This thesis is based on the following papers:

- I. **Anna Hermansen**, Rune Hedlund, Ludek Vavruch, Anneli Peolsson
A comparison between the carbon fiber cage and the Cloward procedure in cervical spine surgery: A 10-13 year follow-up of a prospective randomized study. *Spine* 2011;36,919-925
- II. **Anna Hermansen**, Rune Hedlund, Ludek Vavruch, Anneli Peolsson
Positive predictive factors and subgroup analysis of clinically relevant improvement after anterior cervical decompression and fusion for cervical disc disease: a 10-to 13-year follow-up of a prospective randomized study. *J Neurosurg: Spine* 2013;19, 403-411
- III. **Anna Hermansen**, Joshua Cleland, Ann-Sofi Kammerlind, Anneli Peolsson
Evaluation of Physical Function in Individuals 11 to 14 Years after Anterior Cervical Decompression and Fusion Surgery - A Comparison between Patients and Healthy Reference Samples and Between 2 Surgical Techniques. *J Manip Physiol Ther* 2014;37, 87-96
- IV. **Anna Hermansen**, Anneli Peolsson, Ann-Sofi Kammerlind, Katarina Hjelm
Women's experiences of daily life after anterior cervical decompression and fusion: A qualitative interview study. Submitted Dec 2014, revised 2015

ABBREVIATIONS & DEFINITIONS

ACDF	Anterior Cervical Decompression and Fusion
cAROM	cervical Active Range of Motion
CIFC	Cervical Intervertebral Fusion Cage
CP	Cloward Procedure
CROM	Cervical Range of Motion device
CSQ	Coping Strategy Questionnaire
EQ5D	EuroQol 5 Dimension
ICF	International Classification of Functioning, Disability and Health
MCID	Minimum Clinically Important Difference
NDI	Neck Disability Index
NME	Neck Muscle Endurance
SES	Self-Efficacy Scale
VAS	Visual Analog Scale

Brief definitions

Daily life	Daily life was defined in this thesis as thoughts, feelings, and actions in the private, occupational, domestic and social/recreational areas of life
Disability	Relates to the negative aspect of functioning and is an umbrella term for impairments, activity limitations and participation restrictions according to ICF
Functioning	An umbrella term for body functions & structures, activities and participation according to ICF

INTRODUCTION

Neck pain is a common condition in the general population with a 12-month prevalence of 30-50% (1). The incidence of cervical radiculopathy has been reported as 83 per 100 000 in a general population (2). In Sweden, approximately 1000 cervical spine surgeries are performed annually due to cervical degenerative disorders (3). Neck and arm pain are common symptoms of cervical radiculopathy, and these symptoms have been shown to cause disability with reduced physical and mental health status (4).

Anterior cervical decompression and fusion (ACDF), with or without an intervertebral cage to add support to the fused segment, is an established surgical treatment of cervical radiculopathy due to cervical disc disease. Surgical outcomes are evaluated from a biomedical perspective with clinical global assessment and radiological evaluations, but patient-reported questionnaires of pain, disability and health are also recommended (5, 6). Good global outcome after surgery (7), as well as reductions in pain and disability has been reported in shorter (6 months to 2 years) and longer (> 3 year) evaluations (8-13). However, when evaluating clinically meaningful improvements in pain and functioning after surgery, the results are less promising with individuals showing remaining pain, physical impairments and disability after surgery (8, 11, 14-17).

Only a limited number of studies after ACDF with more than 10-year follow-ups exist (12, 13), and more 10-year follow ups have been recommended (18). There are no previous 10-year follow-ups of ACDF comparing the two surgical techniques; Cloward Procedure and the Cervical Intervertebral Fusion cage (CIFC), or evaluating self-reported and physical functioning. Providing long-term beyond 10 years is important for understanding the sustained effects of, or remaining disability after, cervical spine surgery. To complement patient-reported measures of disability, clinical tests of physical function and self-reported psychosocial factors are indicated to provide information on possible areas to integrate in rehabilitation programs. Qualitative interview studies may further contribute by providing a deeper understanding of the patients' perspectives on outcomes and experiences of daily life after surgery, and contribute to a more patient centered care and rehabilitation after surgery. No qualitative interview studies exploring individuals' experiences of daily life after cervical spine surgery have previously been published.

BACKGROUND

Anatomy and biomechanical function of the cervical spine

The cervical vertebral column encloses and protects the spinal cord, the cervical vertebral bodies support the head, and the facet joints and discs provide flexibility necessary to correctly position the head (19). The first two segments of the cervical spine are atypical with different shaped vertebrae and joints, and lack intervertebral discs. The occiput – atlas joint allows only nodding, and the atlanto-axial joint provide approximately 40 % of cervical rotation (20). The typical cervical segments start at the C2-3 level, however a slight difference in the positioning of the facet joints affecting segmental mobility is seen at the C2-3 level (20).

The cervical intervertebral discs consists of the annulus fibrosus, and the nucleus pulposus (21, 22). The intervertebral disc functions to promote and guide flexibility, and as a shock absorber. The annulus fibrosus consists of layers of fibrous concentric lamellae (21). In the cervical spine, the annulus fibrosus has a crescent shape with a thick anterior part, a thinner or even incomplete posterior part, and with an incomplete annulus at the unco-vertebral space (21, 22). The dorsal part of the disc is covered by the posterior longitudinal ligament (21). The nucleus pulposus is the central mass of cartilaginous matrix with collagen fibers, and is less gelatinous than the lumbar intervertebral disc. Developing from early years of life, an intra-disc cleft runs transversally through the disc (21, 22). Due to the shape of the annulus fibrosus, the nucleus is oriented slightly posterior to the center of the disc (21, 22). The outermost parts of the annulus fibrosus is vascularized and the nucleus is avascular, and the disc is nourished by diffusion from blood vessels of the annulus or the vertebral endplates (23). The outermost part of the annulus and the posterior longitudinal ligament are innervated with nerve endings capable of nociception (23).

The facet joints guide movements of the cervical spine by their orientation (24, 25) and allow much mobility by their loose joint capsules. The capsule and sub-chondral bone of the facet joints are richly innervated with sensory nerve endings (24). Specific to the cervical spine are the uncovertebral joints at the posterior corners of the intervertebral bodies (26).

There are 8 cervical spinal nerves. The 3rd to 8th nerves exit the spinal cord and continues through their respective intervertebral foramina. The intervertebral foramina are constituted of the facet joints posteriorly and the intervertebral disc anteriorly, the pedicles of the inferior and superior vertebral bodies as floor and

ceiling respectively, and processus uncinatus medially (27). The cervical spinal nerves innervate the neck, shoulders and arms. The dorsal rami of spinal nerves innervate the facet joints and the dorsal neck muscles.

The cervical region present with the largest range and variety of movement of the spine (20). Stability of the spine is provided by three subsystems; passive, active and neural systems (19). The passive component consists of the anatomic structure of the spine; the orientation of the facet joints, the uncovertebral joints and the ligaments (19). The main stabilizing effect of the passive system is thought to occur in situations at the end range of movement (19). The passive subsystem also provides information on vertebral positions and movements to the neural control system through a number of proprioceptive receptors. The neural control system decides on the need of muscle contribution and the magnitude of the force (19). It has been shown that the passive osteo-ligamentous cervical spine may carry loads of 20-25% of the weight of an average head indicating a major role of cervical muscles for mechanical support (28).

The active system consist of muscles and tendons attached to the spine (19), which creates a muscle sleeve providing stability in all head positions (29). The longus colli (29) and the multifides (30) are thought to be the prime stabilizers due to their segmental attachments to the vertebrae and the high proportion of slow-twitch muscle fibers (31). The stabilizing muscles act together as agonist/antagonists to provide stability in voluntary movements (32, 33). The sternocleidomastoid is thought to be the main flexor (34) of the cervical spine. The splenius capitis, semispinalis capitis and the semispinalis cervicis are presented as the main extensors (32).

In addition to providing support, protecting the spinal cord, and providing mobility, the cervical spine is also involved in the somatosensory subsystem of postural control. This is due to its function to stabilizing and move to orient the head (thus providing a platform for the vestibular organs and the postural role of the somatosensory system) (20), and to the number of proprioceptive receptors in joints, ligaments, and musculature (predominantly the deep dorsal cervical muscles) (31, 35).

Degenerative disc disease and cervical radiculopathy

Degenerative changes of the cervical spine are a part of natural ageing and are often asymptomatic (36, 37). Over a 10 year period, 81% of initially non-symptomatic individuals of ages 11-77 included in one study presented with degenerative changes to the cervical disc (37). Age was the only factor that was positively correlated with degenerative changes. However, more frequent progression of degeneration was present in those individuals (34% of the total

participants) at 10 year follow-up that experienced pain and/or stiffness of the shoulder (37).

Degenerative changes to the cervical spine begins with the disc (24, 26), leading to a reduced ability to withstand compression, altered biomechanics and alignment of the spine which subsequently causes degeneration of surrounding structures including the facet and uncovertebral joints (23, 26). Cervical nerve roots and/or the dorsal ganglion may become compressed posteriorly from the bony hypertrophy of the facet joints (27, 38), anteriorly by degenerative changes to the disc, disc herniation and hypertrophy of the uncinate joints (27, 38) (see Figure 1).

Figure 1. Overview of degenerative changes to the cervical spine and causes of cervical radiculopathy

Cervical radiculopathy caused by either disc herniation or cervical spondylosis in the USA was found in approximately 83 per 100 000 (men 107 per 100 000, women 64 per 100 000) (2), with a peak incidence at the ages 50-54 (2). The segment commonly affected by cervical spondylosis is said to be the C5/C6 (37), possibly due to it being the most mobile segment (25). In contrast to these findings, the study by Radhakrishnan (2), reported that the most commonly affected segment in individuals with symptomatic radiculopathy was C6/C7, followed by C5/6, C4/5 and C7/Th1.

Cervical radiculopathy causes radicular pain in either one or both upper extremities according to the affected nerve root(s). Sensory and motor disturbances are frequent symptoms. Axial pain (neck pain) may or may not be present in cervical radiculopathy (6, 39). Radicular pain can be caused by mechanical pressure on the nerve or the nerve root (see Figure 1), and/or by a toxic effect from the disc (38). Neurogenic chemical pain mediators from the affected sensory neurons or chemical agents from disc tissue may initiate and/or sustain inflammatory responses (40, 41). Oedema and hypoxia of the nerve root and dorsal ganglion may cause radicular pain (38) or, when sustained, alter the sensitivity of the nerve root to pain (40). Axial pain in degenerative disc disease may be caused by free nerve endings in the cervical disc, facet joints and/or ligaments (24, 41). Axial pain in degenerative disc disease might also be secondary to persistent radicular pain, rather than being related to the degeneration itself.

Management of cervical degenerative disc disease

To date, there is inconclusive evidence for the most effective management of radiculopathy due to cervical degenerative disc disease without myelopathy. No superior conservative treatment (42), or surgical treatment method (18) has been found, and there is a lack of evidence regarding the appropriate postoperative rehabilitation (43). Also, the current evidence does not show significant benefit of surgical treatment compared to conservative treatment (44). The clinical decision making process regarding when and which individuals to include for surgery for cervical degenerative disc disease cannot be made on evidence at this time.

Conservative treatment

Most symptoms of cervical radiculopathy substantially improve within 4-6 months (45). A number of non-surgical treatments including analgesics, traction, unspecified physical therapy, cervical collar, neck-specific training and manual therapy have been used to treat cervical radiculopathy (42). Studies of conservative treatments differ in outcome measures, treatment protocols and lack a common diagnostic criteria for diagnosing cervical radiculopathy, and no recommendations can be made regarding an optimal conservative treatment method (42).

Surgical treatment

Surgical interventions to treat cervical radiculopathy are indicated when clinical radiculopathy is present with active nerve root compression confirmed by MRI, and conservative treatment has failed (39). The main goal of surgery is to provide rapid relief of arm pain, and to reduce current and prevent further neurological symptoms (5, 7). There are no clear recommendations regarding the timing for surgery (39), mainly due to the limited amount of studies (46). However, it has

recently been shown that patients who were surgically treated within 6 months after onset of symptoms had better reductions in arm pain scores than those treated more than 6 months after onset of symptoms (47). In 2013, 983 surgical procedures to treat degenerative cervical spine disease were registered in Swespine, the National Swedish Spine Registry. Anterior implants were used in 69% of the cases and an equal number of men and women underwent surgery (3).

ACDF is an established method to treat radiculopathy caused by degenerative disc disease. The anterior approach is performed by entering through the front of the neck and spine. Decompression involves removal of the disc and the osteophytes to decompress the impinged nerves. With the fusion technique, a structural support is incorporated to replace the disc and to restore disc height, as well as providing fusion, and thus stability of the segment. The Cloward Procedure and Smith-Robinson techniques were first introduced in the 1950's (48, 49). Since then, different techniques, using cages of different materials instead of autologous bone, as structural support have been developed and evaluated. However, there is no evidence in favor of a specific technique with or without a cage when evaluating clinical outcomes (7, 18). One advantage of using a cage compared to autologous bone material is reduced donor site pain (10, 18). The use of a cage is also proposed to maintain segment height, and to improve stability of the segment (18, 50). Similar subsidence of the segment has been found with and without a cage (51), and there are conflicting results regarding the effect of fusion on clinical outcome (8) suggesting a limited or no effect of a cage on clinical outcomes.

Radiological studies have shown that approximately 25% of patients present with symptomatic adjacent segment disease (radiculopathy or myelopathy of a segment adjacent to the fused segment) within 10 years after anterior cervical spine surgery (52). A higher incidence of progressive adjacent segment degeneration over a ten-year period was present in individuals after ACDF surgery compared to asymptomatic volunteers, however this degeneration was not always symptomatic (53). ACDF is thought to accelerate the degenerative process of adjacent segments to the cervical spine by reduced segmental mobility at the fused level, with compensatory motions at adjacent levels, and also by altered centers of rotation that will change the facet joints and disc annulus loading forces (54).

ACDF with or without structured rehabilitation has been shown to provide a more rapid pain reduction (55, 56), and faster improvements in motor and sensory function (56) compared to structured rehabilitation alone, pragmatic physical therapy or soft collar. Despite these early differences, no significant differences in pain, disability or physical function between the surgically and conservatively treated groups were present at 15-month (57) or 2-year follow-ups (16, 55). A number of review studies have found no clear benefits of surgical treatment compared to conservative treatment of neck pain with or without radiculopathy (44, 58).

Postoperative rehabilitation

There is a lack of guidelines for postoperative rehabilitation after cervical spine surgery (43). Postoperative rehabilitation programs after cervical spine surgery have not been evaluated. Active postoperative rehabilitation after lumbar spine surgery due to disc disease or spinal stenosis has been shown to be more effective than usual care (59). Since active postoperative rehabilitation might be effective for lumbar spine, it might be reasonable to expect that it might help in cervical spine as well. An ongoing study is currently evaluating the added benefit of a structured rehabilitation program to outcomes after cervical spine surgery due to degenerative disc disease (43).

Regional clinical guidelines in Sweden include advice (to stay physically active, to maintain a correct posture, etc.), regimen (no heavy lifting or driving a car, and minimize overhead work for approximately six weeks) and range of motion (ROM) exercises targeting the neck and shoulders. Patients are usually referred to, or recommended to contact, a primary healthcare physiotherapist for further rehabilitation.

Outcomes of ACDF surgery

A recent review including studies of various kinds of cervical spine surgery showed a recovery rates after surgery of approximately 80% (as rated by surgeons) (7), and 75-80% (as rated by patients) (8, 60). Reduced neck- and arm pain, and reduced disability are also common outcomes after ACDF surgery (8-11, 60-62). Only a few studies have reported outcomes of 10 years or more after ACDF surgery (12, 13). These studies show improvements in pain and reduced disability ratings at long-term follow-ups compared to preoperative ratings, and recovery rates of 80% as evaluated by surgeons (12, 13).

A variety of factors have been proposed to predict an improved outcome after surgery including single-level soft disc disease, short symptom duration, radicular pain, male gender, non-smoking status, current work status, and preoperative pain and disability (11, 63-67). A few studies included multivariate statistics to evaluate the relative importance of each predictor (11, 63, 67). In one study (63), a clinically relevant improvement (improvement of > 15 in Neck Disability Index (NDI) score) as a criterion for successful outcome, and one study used the NDI change score as outcome (11).

In spite of the group level improvements, a large proportion of patients still present with remaining pain and neck-specific disability in the short (6 -24 months) (8, 14) and long-term (> 3 years) (17) after surgery. Only a few studies have evaluated neck-related physical function measured as cervical active range of motion (cAROM), hand-strength, postural control, neck-muscle endurance (NME) and neck-muscle strength after ACDF, and only at follow-ups between 6 months

and 3 years. These studies showed reduced physical function after ACDF (14, 15, 17, 68, 69).

Aspects of evaluating outcome after cervical spine surgery

Evaluating functioning

The International Classification of Functioning, Disability and Health (ICF) (70) is a conceptual framework for describing and organizing information on functioning and disability related to a certain health condition. The ICF is based on the bio-psychosocial model and regards functioning and disability as based on the interaction of the specific health condition (disease, disorder or injury) with the environmental and personal factors as described in Figure 2 (70).

Figure 2. Interactions between the components of the international classification of functioning, disability and health (ICF) (70). Body Functions & Structure, Activity and Participation are incorporated within the umbrella term of Functioning. Impairments, activity limitations and participation restrictions are incorporated under the term Disability. This figure is modified from its original version (70).

The term Functioning used in the thesis is based on the ICF. Within the ICF framework, functioning is an umbrella term incorporating the components of body function and body structures (functioning at the level of the body), activities (functioning at the level of the individual) and participation (functioning of a person as a member of society) (70). Disability relates to the negative aspect of functioning and is the umbrella term for impairments (deviations or loss of body functions and/or structures), activity limitations (difficulties in executing activities) and participation restrictions (problems experienced in involvements in life situations) (70). Contextual factors represent the background of an individual

and include environmental factors and personal factors (Figure 2). Environmental factors include the physical, social and attitudinal environments in which individuals live and conduct their lives. Personal factors include gender, education, coping strategies and overall behavioral pattern (70).

A number of ICF core sets have been developed to evaluate functioning in different health conditions including low back pain (71), however no core sets are available for assessing disorders of the cervical spine or outcomes after cervical spine surgery. To evaluate how patients perceive outcome of spine surgery, it has been proposed that pain (axial and radicular), health, and disability measures should be used (5). Common patient-reported outcome measures after ACDF are pain ratings, the NDI, and global perceived effect (6). Short Form 36 and Short Form 12 (to evaluate quality of life) are also recommended outcome measures (6). In addition to patient-reported outcomes, clinical assessment of neurological symptoms, factors related to the surgical procedure such as fusion rates, sagittal alignment, and complications are often recorded in evaluations. Evaluating physical function using clinical measures may also provide valuable information on conditions for good functioning in everyday activities.

Psychosocial factors have been shown to be related to the development of neck and back pain, and to the transition from acute to chronic pain (72). Such factors include cognitive factors (attitudes and beliefs), emotional factors (depression, anxiety and distress), and patient-reported poor health (72). Social factors such as family and work issues also appear to be related to pain and disability. (72) In lumbar disc surgery, pain-related fear of movement, the use of passive coping strategies and negative outcome expectations have also been evaluated and shown to be associated with poor outcomes in pain and disability (73). The results from other pain conditions, and from lumbar surgery give a rationale for inclusion of psychosocial factors in evaluation of patients after cervical spine surgery.

Male gender has been shown to be a predictor of successful outcome after ACDF surgery (65). Gender differences in the prevalence or incidence of neck pain differ depending on how neck pain is defined (defined by clinicians or patient-reported). Neck- and arm-pain have been shown to be more frequently reported by women than men (1, 74), but women are less frequently diagnosed with a specific neck disorder (1, 2). Men and women has also reported domestic consequences of, and possibilities to prioritize their own health related to neck and shoulder pain somewhat differently (75).

Perspectives on evaluating surgical outcome

Outcome scores in studies are traditionally analyzed using statistical methods to evaluate the statistical significant group mean change after intervention between groups, and compared to baseline scores. As an alternate approach, intended to evaluate the meaningfulness of changes in outcome scores, the concept of minimal clinically important difference (MCID) was introduced (76). The MCID value

provides a threshold to which individual scores can be compared, in order to evaluate improvements of individual patients (77). In cervical spine surgery research, values for both neck and arm pain (numeric rating scales), and disability (NDI) have been established (78).

Both questionnaires and other patient-reported outcome measures of pain, function, psychosocial factors, as well as measures of physical function are developed and evaluated from the perspective of the healthcare professionals by using predefined categories and thereby limiting the responses. With this, the clinicians also decide on the important aspects of outcomes. Such methods provide quantitative, statistical data to compare and explain outcomes, and possible generalization of results. To explore the patients' perspective of a phenomenon, qualitative research methods can be used. Qualitative methods using semi-structured research interviews can provide a rich and deep understanding on how patients' experience their own reality (79, 80). Exploring patients' views may provide new insights in evaluating outcome after surgery, and enhance the understanding of what may be important to consider in postoperative care and rehabilitation, thus improve patient- centered care.

Rationale of the thesis

Previous studies of outcomes after ACDF surgery have shown improvements in pain and reduced disability after surgery (8-11, 60-62). However, the few studies previously evaluating physical function have despite this shown remaining impairments (14-17, 61, 69). These studies have, with a few exceptions had 6 months to 2 year follow-ups. A variety of demographic, functional and surgery related factors predictive of good surgical outcomes have been identified in previous research (11, 63-67). However, only a few studies have used a multivariate approach to evaluate the relative importance of each factor on outcome. The use of an intervertebral fusion cage in the ACDF procedure has the theoretical advantage of better maintaining segment height and stability of the fused segment than using only autologous bone (18). However, no differences in clinical outcomes have been seen between these techniques (18).

The current literature is limited by the fact that no previous studies have evaluated multiple dimensions of patient-reported functioning and psychosocial factors, or compared outcomes between ACDF techniques using autologous bone or an intervertebral cage more than 10 years after ACDF. Only a limited number of studies have evaluated clinical measures of physical function after ACDF, none of which were conducted as 10 year follow-ups. While male gender has been shown to be a predictor of a positive outcome after ACDF, gender differences have not been adequately described or evaluated. In addition, no previous studies have explored the patients' perspectives after ACDF surgery.

This study is the first to evaluate functioning and to compare the Cloward Procedure with the Cervical Intervertebral Fusion Cage functioning more than 10 years after ACDF surgery. The study is also first to combine the perspectives of clinicians and patients to broaden the knowledge and provide a better understanding of outcome after ACDF surgery. Evaluation of functioning more than 10 years after cervical spine surgery may provide knowledge on whether the early improvements after surgery a. Knowledge on functioning and the patients' perspective may also guide clinicians to provide a better postoperative care and rehabilitation.

AIMS OF THE THESIS

General aim

The overall aim of the thesis was to evaluate long-term functioning after anterior cervical decompression and fusion surgery due to cervical disc disease, and to provide new insights into patients' experiences of daily life after surgery.

Specific aims

- To compare the outcomes of anterior cervical decompression and fusion using the cervical intervertebral fusion cage with the Cloward procedure at 10 years or more after surgery, using a broad clinical and patient-centered assessment (paper I).
- To identify factors that predict a successful outcome 10–13 years after surgery, with “successful outcome” defined as an improvement in neck-related pain intensity and neck-specific disability that exceeds a set threshold of minimal clinically important difference (paper II).
- To investigate sub-group differences between patients with and without a successful outcome, and to investigate gender differences (paper II).
- To evaluate neck-related physical function in individuals 11 to 14 years after anterior cervical decompression and fusion, and to compare the outcomes of neck-related physical function between the cervical intervertebral fusion cage and the Cloward procedure (paper III).
- To evaluate neck-specific impairments in individuals long-term after anterior cervical decompression and fusion surgery (paper III).
- To explore and describe how women, after anterior cervical decompression and fusion surgery, experience their daily life (paper IV).

METHODS

Design

This thesis consists of three studies which resulted in 4 papers. An overview of the studies is presented in Table 1.

Table 1. Overview of studies included in the thesis

Study	A	B	C
Design	Longitudinal follow-up of RCT Cross-sectional observational	Cross-sectional observational	Qualitative interview study
Data collection	Patient-reported outcome measures	Clinical measures	Semi-structured interviews
Time to follow-up after surgery	10-13 years	11-14 years	1.5 -3 years
Number of participants	73 (39 women, 34 men)	51(30 women, 21 men)	14 women
Treatments	CP n=34, CIFC n=39	CP n=25, CIFC n=26	ACDF n=5, ACDF + Rehab n=9
Age Median (range)	61 (42–79)	60 (42-73)	52 (39-62)
Neck-related pain intensity (mm VAS) Median (range)	32 (0-95)	18 (0-76)	
Moderate or severe pain n (%)	38 (53%)	15 (29%)	
Neck-related disability (% NDI) Median (range)	30 (0-80)		19 (0-56)
Moderate or severe disability n (%)	38 (52%)		4 (29%)

RCT = Randomized controlled trial

CP = Cloward Procedure, CIFC = cervical intervertebral fusion cage

ACDF = anterior cervical decompression and fusion,

Rehab = Structured postoperative rehabilitation program

NDI = Neck Disability Index, VAS = Visual Analog Scale

Moderate or severe pain: ≥ 30 mm VAS, Disability moderate or severe: $\geq 28\%$ NDI

Study A was a longitudinal cohort study based on clinical and patient reported data used to evaluate and predict the long-term outcomes of a prospective randomized controlled study (RCT) of two ACDF techniques. Within study A was also a cross-sectional analysis of patient reported outcomes (Paper I and II).

Study B was a cross-sectional study based on physical measures of function including a sub-group of individuals who participated in study A (Paper III).

Study C was a qualitative explorative descriptive study with data collected through individual semi-structured interviews of women after ACDF (Paper IV).

Inclusion

The participants in study A and B were recruited from a randomized controlled trial (RCT) by Vavruch et al. (10), comparing the 2-year outcome of ACDF surgery of the Cloward Procedure to a cervical intervertebral fusion cage (CIFC) made by carbon fiber. At original inclusion, 103 consecutive patients at a University Hospital in the south of Sweden (1995–1998) were randomized to treatment with either the CIFC (10) or the Cloward Procedure (48) by a blinded attending nurse who selected a note marked either Cloward Procedure or CIFC for each patient (10). See table 2 for inclusion and exclusion criteria.

Table 2 Inclusion criteria of the original randomized controlled trial (10).

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> • ≥ 6 months of cervical radiculopathy of degenerative origin with or without neck pain • MRI and clinical findings of cervical nerve root compression 	<ul style="list-style-type: none"> • myelopathy • psychiatric disorder • drug abuse • previous spine surgery

MRI = magnetic resonance imaging

All patients provided informed consent prior to inclusion. Randomization resulted in a similar distribution of age, gender, number of operated levels, duration of symptoms, and smoking habits in the two groups. Eight patients (3 patients randomized to the CIFC group and 5 to the Cloward procedure group) refused surgery, leaving 95 patients in the original study (10).

Inclusion criterion at the 10-year follow-up was to have participated in the original study (10). One individual had had acquired a whiplash associated disorder after surgery and was therefore excluded, and four individuals included in the original study had died, resulting in 90 individuals who were available to participate. At a minimum of 10 years after surgery, questionnaires were mailed to all the remaining 90 individuals still available for participation (see flow chart, Figure 3).

Figure 3. Flow-chart of the inclusion process (Study A and Study B)

CP = Cloward Procedure, CIFC = Cervical Intervertebral Fusion Cage

RCT = Randomized Controlled Trial, WAD = Whiplash Associated Disorder

The current addresses of the remaining individuals at the time of this follow-up were identified through healthcare registers. All informants received written information about the study and provided consent by signing and returning the questionnaire. As a part of the questionnaires in Study A, all individuals were asked if they were willing to participate in a subsequent study (Study B) regarding neck mobility, hand strength, neck-muscle endurance and balance. Fifty-seven individuals provided written consent to participate in Study B and were contacted to schedule the clinical examination. Six individuals dropped out of the study before the clinical examination. Two individuals dropped out due to medical reasons unrelated to their neck problems and 4 were unable to attend any of the scheduled testing opportunities for different non-medical reasons (see flow chart Figure 3).

Informants included in Study C were recruited from an ongoing multicenter RCT in south-eastern Sweden investigating the effect of a structured postoperative rehabilitation program on outcomes after surgery for degenerative cervical disc disease (43). See Table 3 for inclusion criteria.

Table 3 Inclusion criteria of the qualitative interview study

	Inclusion criteria	Exclusion criteria
For the multicenter study	<ul style="list-style-type: none"> • MRI verified cervical disc disease • Clinical findings of nerve root compression • ≥ 2 month of nerve root pain 	<ul style="list-style-type: none"> • Myelopathy • Previous fractures or spinal tumor • Spinal infection • Previous surgery in the cervical column • Systematic disease that contraindicates treatment program • Severe psychiatric disorder or drug abuse • Non-Swedish speaking
For the interview study	<ul style="list-style-type: none"> • Individuals 18-36 months after ACDF surgery • Female gender • Participating/participated in an ongoing multicenter study evaluating the effect of a postoperative rehabilitation program after ACDF 	<ul style="list-style-type: none"> • Presence of musculoskeletal pain or other medical conditions that would considerably influence the informant's daily life

MRI = magnetic resonance imaging, ACDF = anterior cervical decompression and fusion

All informants had, in accordance with the RCT protocol, previously completed questionnaires and participated in clinical testing of neck-related physical function. A purposeful sampling strategy was used to obtain rich descriptions of how individuals experience their daily lives after surgery. The sampling procedure aimed at establishing maximal variation by including informants differing in age, County council, postoperative rehabilitation, family and work situation, and also being from geographical location (urban or rural settings). Only women were included in the interviews because previous research has shown male gender to be a predictor of positive outcome after surgery (66, 67), and the results from Study A and Study B showed that women had a worse outcome than men in pain, disability and psychosocial outcomes. The inclusion was performed parallel to the data collection and to the analysis.

Participants

Study A

Seventy-three individuals (39 women, 34 men, median age 61 years, range 42-79 years) completed the questionnaire-battery at the more than 10-year follow-up (table 1). Seventeen patients did not complete the questionnaire despite several reminders; thus, 88% of all potential participants, or 77% of those initially operated on, answered the questionnaires.

Of the participants, 46 individuals had been operated on at one cervical level, 24 at two cervical levels, and 3 at three cervical levels. Thirty-four individuals had been operated with Cloward Procedure and 39 with the CIFC. Ten patients had at least one additional surgery during the follow-up period (non-significant between groups). According to 2-year radiographs, the operated segment(s) were fused in 50 of the 73 participants, with a significant difference between groups (fusion rates: Cloward procedure = 82%, CIFC = 59%, $p = .04$). Of the additional surgeries, 6 were among those with pseudarthrosis at 2 years (3 reoperation and 3 on adjacent level) and 4 were among those with healed fusion (3 reoperation and 1 on adjacent level).

There was a similar distribution between the two surgical groups regarding age, gender, preoperative pain and disability ratings, and number of operated levels.

There were no differences between men and women in background data except that women had higher preoperative pain ratings than men ($p = .045$). Women also had significantly lower fusion rates at 2-year radiographs ($p = .004$).

Study B

Fifty-one individuals (30 women, 21 men, median age 60 years, range 42-73 years) participated in the clinical examination of cAROM, hand-grip strength, static and

dynamic balance, neck-muscle endurance (NME), and completed pain ratings. Thirty-four individuals had been operated on at one level, 16 at two levels, and 1 at three levels. Twenty-five individuals had been operated on using the Cloward Procedure and 26 with the CIFC technique. Six individuals (Cloward Procedure 2, CIFC 4) had had at least one additional surgery during the follow-up period (non-significant between surgical groups), and 14 had a non-healed fusion on radiographs at the 2 year follow-up (non-significant between groups). Seven individual were left-handed. There were no significant differences between the two surgical groups regarding age, gender, preoperative pain and disability ratings, or number of operated levels. The only difference in background data between men and women were the fusion rates at the 2-year follow-up ($p < .001$).

The only significant difference between the individuals who completed the questionnaire at the 10-year follow-up (Study A) but who did not participate in the measures of physical function and those who did (participants of study B) was in their ratings of health related quality of life ($p = .009 - .04$).

Study C

Fourteen women aged between 39 and 65 years (median 52 years) participated in the interviews. Time from surgery to follow-up ranged from 18 to 33 months (mean 25 months). Nine informants had received customary postoperative rehabilitation provided at the surgical clinic plus a structured rehabilitation program, and 5 informants had received customary postoperative rehabilitation alone. The informants were a heterogeneous group with regards to education, employment status and type of work. Disability scores varied from 0 to 56 (median 19). Twelve women were married or currently living with their partner.

Ethical considerations

This study was performed in accordance with the Declaration of Helsinki ethical principles for medical research. All participants provided written informed consent to participate prior to inclusion. The study was approved by the Regional Ethics Review board in Linköping, Sweden (Dnr: M119-08, 2010/101-32, 2012/416-31).

All data from the questionnaires, the test scores, as well as the recorded and transcribed material from the interviews were anonymized and stored in a secure locker/safe at Linköping University. Only coded data was discussed among the involved researchers. If the participants had physical impairments and wished for additional treatments, they were referred to their appropriate primary health care physical therapy clinic. The strategy to address any problems detected during the interviews that required professional attention, was to recommend the individual

to contact an appropriate primary healthcare professional. This was however not necessary with any of the informants.

Taken together, these studies aim to improve the care and rehabilitation of patients after ACDF surgery and were designed to make no harm to any patients. Participants in the physical function study (Study B) also received a physical assessment. Informants in Study C were given the time and opportunity to reflect on their daily lives and factors affecting it. This may have helped to guide the informants in improving their own life situation.

Interventions

Surgical and rehabilitation treatments for participants in study A and Study B

The Cloward procedure was performed according to standard techniques using bicortical iliac autograft to fill the empty disc space after removal of the disc and osteophytes (10). The autograft was harvested through a 5-cm skin incision using a Cloward dowel cutter (48). The CIFC surgical technique (10) is performed in a similar way to the Smith-Robinson technique (49), with the addition of a carbon fiber cage to support the segment.

Postoperatively, all patients used a Philadelphia collar for six weeks, and most received customary physiotherapy (information/advice from the physiotherapist at the neuro-surgical clinic, not designed specifically for the study) with a referral to a physiotherapist in primary healthcare after removal of the collar, if needed.

Surgical and rehabilitation treatments for participants in Study C

ACDF was performed using cages filled with autologous bone to fuse the segment after removal of the disc and the osteophytes. In 2-level fusion, an anterior plate was most often added. The standard cages used at each neuro-orthopedic center were used. No iliac crest grafts were used.

Postoperatively, all individuals received standard care after ACDF surgery including information and routine follow-ups by surgeons and other health-care professionals. Participants were also randomized to two postoperative rehabilitation programs. Participants received either customary rehabilitation (information/ advice from the physiotherapist at the neuro-orthopedic/neuro-surgical clinic with a recommendation to contact a primary health care physiotherapist if needed) or customary rehabilitation plus a rehabilitation program that included neck-specific exercises combined with a behavioral approach (43).

Data collection

Data was collected with patient-reported outcome measures, clinical measures, and semi-structured individual interviews. An overview of outcome measures included in the study is presented in Table 4.

Table 4. Overview of outcome measures included in the thesis

	Study A	Study B	Study C
Patient-reported outcome measures			
Pain intensity (100 mm VAS)	x	x	
Distribution of pain (pain drawings)	x		
Frequency of symptoms (5-grade scale)	x		
Current use of pain medication	x		
Neck-related disability (NDI score)	x		x
Impact on daily life (6-grade scale)	x		
Work status	x		x
Global perceived effect (6-grade GPE scale)	x		
Perceived change of symptoms	x		
Expectations met	x		
Health-related quality of life (EQ-5D, EQ VAS)	x		
Coping strategies (CSQ scores)	x		
Self-efficacy (SES)	X		
Clinical measures of physical function			
Cervical active cervical AROM (CROM)		x	
Hand-grip strength (Jamar®)		x	
Neck-muscle endurance		x	
Static balance (sharpened Romberg's test)		x	
Dynamic balance (Walking in a figure-of-eight)		x	

VAS = Visual Analog Scale, NDI = Neck Disability Index,

EQ-5D = EuroQol 5 dimensions, CSQ = Coping Strategy Questionnaire,

SES = Self-efficacy Scale, AROM = Active Range of Motion, CROM = Cervical Range of Motion device

Patient-reported outcome measures

The patient reported outcomes in study A were collected through an extensive questionnaire-battery sent to the participants at a minimum of 10 years (10-13 years) after their inclusion to the original RCT. The outcome measures included were loosely based on the domains of a core set for low back pain research (81). The outcome measures and single-item scales regarding pain and symptoms, disability and psychosocial factors were self-assessed by the participants. Neck-related pain intensity was also evaluated at the time of clinical testing and disability was assessed at the interview session.

Pain and neurological symptoms

Current neck-related pain intensity was measured using a horizontal 100 mm Visual Analogue Scale (VAS), and separate ratings were recorded for neck and arm pain and headache. It is recommended to assess pain ratings of both axial or local pain, and radicular pain in patients with spinal disorders (5, 81). The unspecific measure of neck-related pain was included in the original study and possible to analyze over time. The 100 mm VAS is a frequently used measure for pain intensity, and has been shown to be valid and reliable in a number of patient populations (82-85). A reduction of 30 mm on the VAS has been established as the MCID in patients with localized musculoskeletal pain after intervention (86) and was used in the thesis to dichotomize individuals as reporting a successful pain reduction or not after surgery (paper II).

Headache has previously been reported by patients with radiculopathy as well as by patients after ACDF surgery (87). Both headache intensity and frequency were evaluated in the study. The sensation of pain is multidimensional (82) and therefore, pain frequency ratings and pain drawings were also included in the long term follow-up questionnaire battery.

Distribution of pain was assessed using pain drawings. These pain drawings were converted to a 7-point scale (0=no pain, 6=most distal) (88).

Patients were also asked whether they had experienced any neck problems during the past 6 months (yes/no). Frequency of neck and arm pain, and headache was rated using a 5-point scale (1=never, 5=constant). For statistical analysis, these ratings were dichotomized to never/occasionally (1-2) or daily/constantly (3-5).

The use of pain medication was rated as never, occasionally, yes every day and yes multiple times a day.

Neurological symptoms of numbness and weakness of the hand(s) were assessed using a 5-point frequency rating scale and dichotomized as the pain frequency ratings.

Disability

Self-reported disability was evaluated using the Neck Disability Index (NDI) (89, 90). The NDI was developed by Vernon as a neck pain equivalent of the Oswestry Disability Questionnaire (91).

The NDI consists of 10 items. Each item is scored from 0 to 5 with a maximum point score of 50 (0 = “no disability”, and 50 = “complete disability”) (89). A percentage score is calculated as the point score divided by the maximum point score (50 if all items are completed) multiplied by 100. Either the point score or the percentage score can be used. The percentage score is predominantly used to account for some internal missing values (92). A Swedish version of the NDI was used in the thesis, (Appendix 1). The continuous percentage score (paper I), and a dichotomized outcome based on a MCID value of 20 score unit change (paper II)

(93) was used in the thesis. NDI as background data (paper IV) was categorized according to: less than 8% = recovered, 10% - 28% = mild disability, and more than 30% = moderate to severe disability (92).

The NDI has been evaluated in different populations with neck disorders, and it is recommended to use in evaluating the effectiveness of ACDF surgery (6). In individuals with cervical radiculopathy who were referred for physical therapy, the NDI has acceptable values for construct validity and responsiveness, and fair test-retest reliability (94). The Swedish version of NDI (Appendix 1) has good validity, sensitivity and excellent test-retest reliability in patients with acute and chronic neck pain, but with low specificity (90). The specificity increased when clearly stated throughout the instrument that each item should be responded to with regards to the pain in the neck (90). The instructions of the NDI included in the 10-year follow-up directed the participants to provide answers related to their present problems, not specifically addressing the neck.

A change score of 20 (percentage unit score) was defined as the MCID in patients with mechanical neck pain (93). In patients who underwent spine surgery due to degenerative disease and ACDF due to radiculopathy, the MCID has been defined as 7.5 points (percentage score equals 15%) (95) and 17.3% (78) respectively.

The impact of neck symptoms on activities of daily life was rated on a 6-point scale (0 = not at all, 0= almost incapacitated).

Work status was rated as not applicable, no, yes fulltime, and yes part-time.

Psycho-social factors

The Self-Efficacy Scale (SES) (96) was used to investigate the individual's confidence regarding his/her ability to successfully perform certain activities despite pain. The Swedish version of the SES (97) was used in the thesis. This version is modified from its original by changing the wording in the introduction to include all the individuals with pain instead of only individuals with low back pain. The SES consists of 20 items describing activities and is rated on an 11-grade numeric rating scale (0= not at all confident, 10 = very confident), with a maximum score of 200 (96, 97). The Swedish version of the SES is proposed to have good reliability in individuals with Whiplash Associated Disorders (98).

Cognitive and behavioral strategies used to cope with pain were recorded using the Coping Strategies Questionnaire (CSQ) (99). The CSQ consists of 8 subscales assessing the use of different strategies to cope with pain (diverting attention, reinterpret pain sensations, positive self-statements, ignore pain, praying/hoping, catastrophizing, increase activity, pain behavior). Each subscale is comprised of a number of items rated on a 7-grade scale (0 = never use it, 6 = always) depending on how accurately they coincide with the individuals' use of the particular item. The score of each subscale is the sum of the ratings of the items included in the particular subscale. The CSQ also includes two questions regarding

the effectiveness of coping strategies (ability to control pain and perceived control over pain), each rated on a 7-grade scale (0 = no control, 6 = complete control). The Swedish version of the CSQ was used in the thesis (100). The translated version has been proposed to have good validity, but less satisfactory test-retest reliability (differed depending on sub-scale) in individuals with longstanding neck, shoulder and/or back pain.

The CAT sub-scale consists of 6 items describing catastrophic thoughts, and has been proposed to have sufficient internal consistency to be used as a separate measure in patients with sub-acute and chronic musculoskeletal pain (97).

Whether or not the expectations of surgery were fulfilled was rated as yes completely; yes partially; no, not at all; or I don't know.

Global perceived effect of surgery was rated by participants using a six-grade global perceived effect scale (101). The scale that was used in the thesis consists of 3 positive outcomes, one neutral, and 2 negative outcomes (0 = complete relief, 5 = much worse). To allow comparisons with other studies after ACDF surgery, the ratings in the present study were dichotomized as successful (better-complete relief, 0-3) or non-successful (unchanged-worse, 4-6) outcome.

The importance of perceived change of symptoms was rated on an 11-grade numeric rating scale (0 = not at all important, 10 = very important).

Symptom satisfaction was rated using five-grade scale with 3 positive outcomes (happy, satisfied, mostly satisfied) and two negative outcomes (not satisfied and unhappy) (102).

Health related quality of life was measured using the EuroQol 5 dimensions (EQ-5D) (103). The scores on the 5 dimensions were converted to an index score between 0 (poor overall health) and 1 (good overall health) (103). Current health status was rated on the EuroQol 100 mm vertical VAS (0= worst imaginable health, 100 best imaginable health) (103). The EQ-5D is a generic instrument and should be evaluated together with more condition specific instruments such as the NDI.

Data collected at previous follow-ups

Preoperatively, and at the 1- and 2-year follow-ups, patients had a standard clinical examination, radiographs (antero-posterior, lateral, and oblique), and responded to questionnaires (10). Preoperative values of cAROM and hand-grip strength were also collected as part of the initial evaluation (66). Preoperative cAROM of six directions (flexion, extension, right and left rotation and lateral flexion) was measured with a cervical measurement system (CMS) consisting of a helmet with two gravity goniometers and one compass. The CMS has demonstrated to be a reliable and valid test of cAROM (104). Right and left hand-grip strength was measured using a Vigorometer.

Ratings of neck-related pain intensity and disability were also collected at the 6 year follow-up (105) (See flow-chart, Figure 3).

Clinical measures of physical function

A clinical examination of physical function was performed starting with cervical active range of motion (cAROM) followed by hand-grip strength, clinical balance tests, and neck muscle endurance (NME) tests. The order of performing the tests was standardized. Participants were given verbal instructions immediately before each measure. No warm-up exercises were performed before the assessment. However, immediately prior to performing the different measures, one sub-maximal test trial was allowed to ensure that the instructions were correctly understood. The only rest allowed was the time taken to rate pain between the different measures, to change positions to the next test procedure, and during the explanation of test procedures. One experienced, independent physical therapist (AH), blinded to randomization performed all measurements. All measurements were performed during the same testing session. To evaluate the effect of the tests on the patients' pain level, current pain was rated before, in-between, and after the different tests.

All of the clinical measures were patient-controlled. Tests stopped on the patients' initiative, thus all measures could be influenced by cognitive factors such as motivation, fear of movement and/or pain tolerance.

Cervical active range of motion

Cervical AROM was measured to evaluate general neck mobility, which is the angular displacement of the head in relation to the thoracic spine (106). Cervical AROM was measured in degrees using a Cervical range of motion (CROM) device (107). Six directions (flexion and extension, rotation right and left, lateral flexion right and left) of cAROM were measured in a seated position (107) (Figure 4). The CROM device has presented with good reliability and construct validity in patients with neck pain, although it has doubtful ratings of agreement and insufficient information regarding responsiveness (108).

Figure 4. Measure of cervical active range of motion

Hand-grip strength

Hand grip strength was measured to quantify the effect of the neurological motor symptoms and arm pain on upper extremity strength. Hand-grip strength was measured in kilograms with a Jamar dynamometer in the standing position with the elbow in 90° flexion, the wrist in neutral and the size of the handle set at the second (women) and third (men) position (109) (Figure 5). Participants were instructed to squeeze the handle as hard as they could for 5 seconds. The peak value was registered (109). Reliability for measuring hand-grip strength with the Jamar in patients with cervical radiculopathy has been shown to be high (109).

Figure 5. Measure of hand-grip strength with Jamar dynamometer

Balance tests

Static balance, i.e. the individual's ability to maintain a position, was tested using the sharpened Romberg's test (110) (Figure 6). Testing was performed in standing with the feet on a straight line in a heel-to-toe position and the non-dominant foot in front of the dominant foot (110) (Figure 6). The test was performed with eyes closed to remove the visual input to the balance system thus placing greater demands on vestibular and somato-sensory systems to maintain stability. The test was measured in seconds and ended if the participant moved the feet from a given position, opened the eyes, touched the wall for support, or maintained the position for 30 seconds (111).

Dynamic balance, i.e. the ability to maintain equilibrium when moving, was measured using the "walking in a figure of eight" (112) test (Figure 7). This test forces a narrow base of support (15 cm indicated with a wide black marker on the ground) when walking forwards in a pattern of eight with a metronome dictating the pace. The total number of incorrect steps (steps on or outside of the lines) in each trial was recorded (111).

Three trials of the each balance test were performed, and the mean of the 3 trials was used for analysis. If the participant reached the maximum value (30 seconds or no incorrect steps, respectively) at the first or second trial, no further trials were performed, and the maximum value was assigned to the remaining trials (111).

Figure 6. Sharpened Romberg's test with eyes closed

Figure 7. Walking in a figure-of-eight

Both the sharpened Romberg's test with the eyes closed and walking in a figure of eight have been found to have good reliability in patients with dizziness of vestibular or central origin (113). The tests have been used when evaluating balance in a number of disease populations and healthy individuals, although they have not been evaluated for validity or reliability in patients after neck-surgery or in patients experiencing dizziness or balance disturbances of cervical origin. It is acknowledged that there are other clinical tests of balance with different degrees of difficulty, although the tests used in this thesis were specifically chosen to be challenging to participants.

Neck muscle endurance

To quantify neck-muscle function, tests of ventral and dorsal NME were performed. The endurance test of the anterior neck muscles used in this thesis was based on an original test presented by Grimmer (114), although with slight modifications. The ventral NME test in this thesis was performed in supine lying with legs straight. Participants were instructed to flex the upper cervical spine, by performing a slight nod, and lift the head just off the examination table (Figure 8). Participants were instructed to stay in this position for as long as possible. The test ended at exhaustion or if participants experienced pain radiating into the arm(s) (115). In one review article, the endurance test of short neck flexors (with or without modifications) was given a positive rating for reliability, but questionable ratings for agreement and validity in patients with non-specific neck pain (116).

Dorsal neck muscle endurance was measured in prone lying, with a weight (2kg for women, 4 kg for men) hung from the participants' heads just above the ears (117). Participants were instructed to extend the upper neck (the tip of the chin pointing towards the floor) (Figure 9), and to maintain the position for as long as possible. The test ended at exhaustion or if participants experienced pain radiating into the arm(s) (115, 117). The dorsal NME test has shown good reliability for healthy individuals and individuals with neck disorders (117).

Figure 8. Measure of ventral neck-muscle endurance

Figure 9. Measure of dorsal neck-muscle endurance

Both ventral and dorsal NME were measured in seconds. The test leader supervised all test positions and provided a maximum of two verbal cues if participants started to deviate from the correct position. The test ended when participants laid down their heads or when they were unable to maintain the correct test position despite two verbal corrections from the test leader.

Qualitative research interview

Socio-demographic information was collected using a structured questionnaire prior to the qualitative semi-structured research interview. An interview guide was prepared before the interview. Interview guides provide an overview of the subject areas of the interview and are often used when performing semi-structured research interviews. Within this guide, the researcher is free to explore, probe, and ask open-ended follow-up questions (79, 118, 119) with the aim to encourage the informant to tell his or her story (80). Semi-structured interviews may provide a rich and deep understanding of informants' experiences of the world expressed in their own words while remaining within the limits of the aim of the study (79).

The interview guide used in study C was initiated by one open question "At this time after your neck-surgery, please tell me about your experiences of your daily life". Further questions were posed about informants' experiences of factors influencing daily life after surgery, thoughts and feelings related to daily life and the future with regard to the surgery they had gone through and possible remaining problems, descriptions of strategies to handle/control possible remaining problems, and also how the informants described possible behavior-related

changes of daily life as a consequence of cervical disease and neck-surgery. The interview guide was developed based on previous research with the patient group and on clinical expertise, in an attempt to broaden knowledge about the patient group by exploring multiple dimensions of daily life after ACDF surgery. The interview guide was discussed among the authors (of paper IV), and peer-reviewed by doctoral students in physiotherapy. Three trial interviews (included in the study) were conducted to validate the interview guide with regard to the aim. This resulted in slightly revised wording of some follow-up questions in the interview guide to more thoroughly explore the areas or factors of daily life that were the most important to each informant.

Interviews were conducted between October 2013 and March 2014. The duration of the interviews varied between 40 to 80 minutes. The interviews were recorded using a digital recorder and transcribed verbatim by the first author.

Analysis

Statistical methods

For differences in main outcomes between the two surgical groups over time, one-way repeated measures analysis of variance (ANOVA) with Bonferroni correction were performed. Pairwise comparisons were performed to analyze differences between different time-points after surgery within the surgical technique groups.

Comparisons between surgical groups and sub-groups were performed using the two-tailed student's t-test or Mann-Whitney U-test for interval and ordinal data respectively. In paper III, all background variables and outcome scores were compared between sub-groups using Mann-Whitney U-test due to small sample sizes. Chi squared tests and Fischer's exact tests were used for group comparisons of categorical data. Differences in impairment rates between men and women were also compared using the Chi squared test (data not previously presented).

Predictors of a successful long-term (10-year or more) outcome in neck-related pain intensity and disability were analyzed with forward stepwise logistic regression. A successful outcome in the two models was defined as: a change score in mm VAS of more than 30 mm VAS (86), and a change score in NDI of more than 20 NDI percentage score units (93). The independent variables included in the models were age, gender, preoperative duration of symptoms, smoking (demographic variables), neck-related pain and disability, sagittal-, frontal-and horizontal cAROM, hand-grip strength (preoperative functioning), and kyphosis and disc height preoperatively; healing status, number of levels operated on (surgery-related variables). The final model of neck-related pain was adjusted for gender due to significant differences in multiple preoperative values including preoperative pain ratings. Results from the logistic regression analysis were presented as Odds Ratio (OR) with 95% confidence interval (CI), and Nagelkerke (pseudoR²).

Bivariate correlations were analyzed using Pearson correlation coefficient (paper I) or the Spearman rank correlations coefficients (paper III).

An unadjusted p-value of $\leq .05$ was considered statistically significant for all analyses. Statview was used for data analysis in paper I. The IBM Statistical Packages for the Social Sciences (SPSS 19 and 21) was used for all other statistical analyses.

Determining impairments

Impairments were determined by comparing the individual participant's values on physical function tests to those of healthy individuals. Each test value for every single patient was compared to cut-off values for age and/or gender matched healthy control groups. Impairment rates for each outcome were calculated by

dividing the number of patients who presented with scores below the cut-off value by the total number of patients participating in the test. An arbitrary cut-off of 2 standard deviations (SD) below the mean reference values was set for cAROM and hand-grip strength (109, 120). For NME and balance, values below the 10th percentile of healthy reference values were considered as impairments (121) (Kammerlind, unpublished data). Depending on the impact of age on neck-mobility these values were divided in age groups (120). Cut-off values used to determine impairments were split by gender depending on men being significantly stronger than women (109). Reference values for hand-grip strength and NME in the oldest age group (65-74), were collected and analyzed as a part of study B

A VAS score of >30 mm was considered as moderate or severe pain (122). A NDI score of 0-8% was considered no disability, 10-28% mild disability, and $\geq$ 30% moderate to severe disability (92).

Sample size

At original inclusion it was estimated that 41 individuals in each group were needed to detect a between-group difference in VAS score of more than 15 mm, with alpha error set to .05 and 90 % power (10). The standard deviation included in the sample size equation was based on pre-treatment values.

Of the 73 participants who completed the questionnaires, 71 and 72 individuals had preoperative and follow-up values that were valid for calculating a change score in neck-related pain and NDI score, respectively. In the sub-group analyses, the internal missing values varied from 0-10. It has been suggested that 10 individuals are required for every explanatory variable included in a logistic regression model (123). Three and one factors respectively were included in the final models of neck-related pain and disability.

Qualitative analysis

Collection and analysis of data proceeded simultaneously (79). The inclusion ended when no new information emerged from additional interviews.

Transcripts were analyzed by the first author using qualitative content analysis. An inductive approach in content analysis was used which allowed patterns, variations, and categories to emerge from the informants' own stories (79). Only the manifest meaning of the text was analyzed. Using an inductive approach and analyzing the manifest meaning was consistent with the aim of the study: to explore and describe the informants' experiences from their own perspective.

Initially, each transcript was read thoroughly to get a sense of each informant's story. During additional readings, statements in the text (quotes) that responded to the aim of the study were identified. Quotes were coded as close to the transcribed text as possible. A code is a label that represents and describes each individual statement. Codes were then systematically compared to find regularities and

variations. Similar codes were sorted into subcategories, and finally into categories (79).

The content within each category should be homogeneous and separate categories should be mutually exclusive (79). The process of sorting codes into sub-categories and subsequently to categories was an iterative process and involved working back and forth between the categories and the data/text to verify the meaningfulness and accuracy of the categories (79).

Trustworthiness in qualitative research

To determine the quality of data collection and analysis in qualitative research, the overall concept of trustworthiness is traditionally used instead of validity, reliability, and generalizability. Trustworthiness is established via the underlying concepts of credibility, dependability, transferability and confirmability (124).

Credibility of research is based on using rigorous methods for fieldwork and systematic analysis but also on the skill, knowledge and beliefs of the researcher (79). To systematically search for not just the one, but alternate patterns to find the best fit is one way of increasing credibility of the analysis and analyst triangulation is another (79). In this thesis, the consistency of codes and categories was checked by and discussed with all co-authors during and at completion of the analysis. This form of analyst triangulation (79) showed high agreement between the authors. Since the researcher is an instrument in qualitative research, the credibility of the researcher is important. The interviewer was a physical therapist with clinical experience in the field of musculoskeletal disorders and trained in qualitative methodology. Also, within the research group, there was one expert qualitative researcher who was not a physical therapist, and who guided the process of the design, data collection and analysis.

Transferability of research findings relates to the extent to which findings may be transferable to other populations or other situations with similar characteristics; the generalizability of results (124). The sampling strategy of maximum variation was used in the present study. This resulted in an information-rich sample including a variety of individuals with regard to demographic and social factors as well as functional outcome, which makes the results of the study transferable to other female populations after cervical spine surgery.

Dependability may be regarded as the degree to which the findings are independent of accidental circumstances, that they are not arbitrarily developed (79, 125). Dependability in this study was achieved through conducting pilot interviews to validate the interview guide, following a systematic analysis process, and thoroughly describing the methods and analysis

Confirmability means that data are linked to their sources (124) and can be thought of as a form of verification of the findings. Confirmability was established by presenting the findings as sub-categories and categories and by providing quotes to illuminate the results and the meaning of the developed categories.

In addition to trustworthiness and the underlying concepts, reflexivity is an important quality criteria (79). Reflexivity emphasizes the importance of self-awareness and self-questioning and also to take seriously the responsibility to communicate accurately the perspective of the informants (79). To be reflexive is for the researcher to reflect about how they have contributed to the production of knowledge, to be sensitive to their own subjectivity and prior understandings, and to be aware of and not confuse the knowledge present in advance with the knowledge emerging from the systematic analysis of the interviews (79).

RESULTS

Quantitative findings

Comparisons between surgical procedures at the 10-year or more follow-up (paper I and III)

Pain intensity was significantly less at the 10-year follow-up compared to preoperatively in both treatment groups (mean differences; Cloward Procedure 37 mm, CIFC 32 mm, $p \leq .001$). A significant decrease in pain was evident at the 2-year follow-up. From 2 years to 10 years there were no significant changes in neck-related pain in either treatment group.

Figure 10. Neck-related pain ratings (mm on a Visual Analogue Scale (VAS)) over time and split by surgical techniques (CP= Cloward Procedure, CIFC = cervical intervertebral fusion cage). There were no significant differences between the groups at more than 10-year follow-up. Both groups were significantly improved from baseline to 10-year follow-up.

Neck-related disability was significantly less at the 10-year follow-up in the CIFIC group (mean difference 6 percentage score units, $p = .04$), but not in the Cloward Procedure group (mean difference 5 percentage score units, $p = .11$). There was an initial improvement at the 2-year follow-up in both groups, but this improvement only remained at the 10-year follow up in the CIFIC group.

Figure 11. Neck Disability Index (NDI) percentage score over time, and split by surgical technique (CP= Cloward Procedure, CIFIC = cervical intervertebral fusion cage). There were no significant differences between the groups at more than 10-year follow-up. Only the CIFIC group was significantly improved at the 10-year follow-up compared to preoperative values.

Overall, there were no group differences over time in either neck-related pain intensity or disability. Further, there were no significant differences in the main patient reported outcomes (neck-related pain and disability) ($p = .94$ and $.36$) or in any of the clinical measures of physical function ($p = .10 - .92$) between the two surgical groups at the 10-year follow-up. There were no significant differences in secondary outcomes between the two groups, except for greater fulfillment of preoperative expectation ($p = .01$) and lower intensity of headache ($p = .005$) in the CIFIC group compared to the Cloward Procedure group. Outcomes at the 10-year follow up are presented in Tables 5 and 6.

Table 5. Long-term patient-reported outcomes of anterior cervical decompression and fusion with either the Cloward procedure or the cervical intervertebral fusion cage.

	Total (73)	CP	CIFC	P-value
Main outcomes				
Neck-related pain (mm VAS) mean (SD)	35 (27.0)	35(24.9)	35(28.6)	.94
NDI (% score) mean (SD)	29 (18.7)	31(18.6)	27(18.7)	.36
Secondary outcomes				
Pain and numbness				
Neck pain (mm VAS) mean (SD)	31 (26.1)	33(25.3)	30(27.1)	.61
Arm pain (mm VAS) mean (SD)	32 (26.6)	34(26.2)	31(27.3)	.67
Headache (mm VAS) mean (SD)	23 (27.4)	33(32.1)	14(19.3)	.005*
Pain radiation to arm median (range)	6 (0-6)	6 (0-6)	6 (0-6)	.10
Daily neck problems n(%) yes	33 (47)	19 (58)	14 (38)	.08
Daily arm pain n(%) yes	29(42)	14 (42)	15 (42)	.57
Daily headache n(%) yes	17 (25)	11 (34)	6 (17)	.10
Pain medication n(%) daily	22 (32)	10 (31)	12 (32)	.93
Daily hand weakness n(%) yes	34 (50)	18 (55)	16 (46)	.31
Daily hand numbness n(%) yes	26 (37)	13 (39)	13 (35)	.45
Neck problems last 6 months n(%)Yes	56 (79)	27(82)	29(76)	.85
Disability				
Impact on daily life n (%)				.60
Quite severe/extremely severe	33 (54)	17(59)	16(50)	
Not all all/ mild	28 (46)	12 (41)	16 (50)	
Neck-related sick-leave n (%)				.16
Yes	23 (33)	12(38)	11(30)	
No	19 (28)	11(34)	8(21)	
Not applicable	27 (39)	9(28)	18(49)	
Psychosocial variables				
Self-efficacy mean (SD)	149(139.2)	145 (43.5)	152 (35.2)	.49
Expectations of surgery met n(%)				.01*
Yes, completely	28 (39)	7(21)	21(55)	
Yes, partially	34 (48)	21(64)	13(34)	
No, not at all	9 (13)	5(15)	4(11)	
CSQ: Catastrophizing Median (IQR)	7 (12.5)	4 (11.3)	9 (14.0)	.16
CSQ: Control over pain Median(IQR)	4 (2.0)	5 (1.8)	4 (2.0)	.52
CSQ: Ability to decrease pain median (IQR)	4 (2.0)	4 (2.0)	3 (1.3)	.21
Importance of change median (IQR)	8 (2.0)	8(0-10)	8(0-10)	.88
Global outcome and health				
Global perceived effect n (%)				.33
Successful	62 (85)	27 (79)	35 (90)	
Not successful	11 (15)	7 (21)	4 (10)	
EQ VAS (mm) mean (SD)	67 (21.7)	64(18.6)	69(24.2)	.28
EQ 5D mean (SD)	.69 (.24)	.67(0.22)	.71(0.26)	.49

CP=Cloward procedure, CIFC = cervical intervertebral fusion cage

VAS = visual analogue scale, NDI = neck disability index, EQ 5D = Euroqol 5 dimensions, 7 other sub-scales of the Coping Strategy Questionnaire (CSQ) not reported in table 5 were non-significant between groups.

An unadjusted p-value of $\leq .05$ was considered statistically significant, marked with *.

Table 6. Long-term outcomes of physical function after anterior cervical decompression and fusion surgery with either the Cloward Procedure or the Cervical Intervertebral Fusion Cage

		Total (51)	CP	CIFC	p-value
cAROM (°)					
	Flexion	34 (30-44)	36 (27-48)	32 (30-42)	.53
	Extension	48 (38.8-58.3)	47 (34-59)	49 (40-56)	.64
	Rot R	50 (42.0-57.0)	50 (41-58)	49 (44-57)	.81
	Rot L	46 (37.0-55.0)	50 (38-50)	45 (38-50)	.30
	Lat Flex R	24 (18.0-30.0)	26 (19-34)	24 (19-28)	.80
	Lat Flex L	24 (17.0-31.0)	26 (16-35)	22 (18-30)	.69
Hand-grip strength (kg)					
	Right hand	30 (20-38)	32 (21-39)	27 (19-38)	.53
	Left hand	30 (22-38)	32 (25-20)	29 (20-38)	.50
NME (sec.)					
	NME ventral	22 (11-40)	28 (14-45)	17 (8-35)	.10
	NME dorsal	71 (26-144)	69 (21-93)	73 (44-146)	.39
Static and dynamic balance					
	Romberg's test (sec.)	7 (4-13)	8 (3-13)	6 (4-14)	.92
	Figure-of-eight (nr. of incorrect steps)	13 (6-21)	12 (6-25)	14 (7-20)	.65

CP = Cloward procedure, CIFC = Cervical Intervertebral Fusion Cage

cAROM = cervical active range of motion, NME = neck muscle endurance

An unadjusted p-value of $\leq .05$ was considered statistically significant

Factors predicting a successful long-term outcome after ACDF surgery (paper II)

Preoperative factors with predictive importance for a successful outcome in neck-related pain intensity at the 10-year follow-up were initial high neck-related pain intensity (mm VAS) (OR 1.06, 95% CI 1.02-1.10, $p = .002$) and non-smoking status ($p = .05$, OR 3.03, 95% CI 1.00-9.12, $p = .05$) (pseudo R^2 for total model = .29). Male gender was the only factor with significant importance for a successful outcome on the NDI ($p = .01$, OR 4.33, 95% CI 1.29-14.59, $p = .01$, pseudo $R^2 = .14$).

Patient-reported differences between sub-groups based on outcome success in neck-related pain and disability (paper II)

Fifty-seven per cent of the participants had a successful outcome in pain intensity (a change score of $\geq$ than 30 mm VAS from preoperative values), and 25% had a successful outcome on NDI (a change score of $\geq$ than 20 NDI percentage score units from preoperative values).

Participants with a successful outcome in both pain ratings and NDI had significantly lower ratings on all pain and disability variables ($p = \leq .001 - 0.4$) at the 10-year follow-up compared to those with an un-successful outcome. In addition, they had better ratings of global perceived effect of surgery, self-efficacy, general health, and experienced fewer neurological symptoms ($p = \leq .001 - .02$). Patients who reported a successful outcome on NDI also scored significantly lower for catastrophizing and reported more control over their pain ($p = .002 - .04$) than those who reported an unsuccessful outcome.

There were no significant differences in background variables between improved and not improved individuals, except for better pre-operative values of neck-related pain intensity in the improved group ($p = .003$).

Gender differences (paper II)

There were no gender differences in the number of individuals who reported successful outcome (≥ 30 mm VAS improvement from baseline) in pain intensity and who did not ($p = .55$), but significantly fewer women than men reported a successful outcome (≥ 20 score points improvement from baseline) on the NDI ($p = .01$).

Women reported more intense neck and arm pain, and had higher NDI ratings at the 10-13 year follow-up ($p = .007$). Women also reported greater catastrophizing and lower self-efficacy.

Significantly more men than women had impairments in ventral NME ($p = .034$) and dynamic balance ($p = .001$) (gender sub-group analysis of physical impairments are previously unpublished). Women had higher preoperative neck-related pain ($p = .01$) but there was no difference in preoperative patient-reported disability ($p = .15$).

Evaluation of physical impairments at 11-14 years after ACDF surgery (paper III)

There were no significant differences in impairment rates in any measure of physical function between the two surgical techniques ($p = .22 - .93$). Twenty-nine per cent of the participants reported moderate or severe pain according to VAS. More than one third had impairments in lateral flexion and rotation, right hand-grip strength, and balance tests; and as many as 63 and 82% had impairments in ventral and dorsal NME respectively (Table 7).

Three measures of physical function were significantly correlated to pre-test pain intensity; cAROM (extension $\rho = -.35$ and rotation bilaterally $\rho = -.30, -.28$), hand-strength ($\rho = -.43$ and $-.32$), and also neck-muscle endurance ventral ($\rho = -.43$) and dorsal ($\rho = -.52$). Neck-extension and right rotation correlated with dynamic balance score ($\rho = -.38, p = .01$ and $\rho = -.30, p = .04$).

Table 7 Amount of participants with impairments in physical function* 11-14 year after anterior cervical decompression and fusion.

Outcome Measure	Total % (n) impairment	CP % (n) impairment	CFIC % (n) impairment
Cervical AROM			
Flexion (50)	18 (9)	35 (6)	12 (3)
Extension (50)	20 (10)	25 (6)	15 (4)
Lateral flexion right (51)	25 (13)	36 (9)	15 (4)
Lateral flexion left (51)	33 (17)	36 (9)	31 (8)
Rotation right (51)	31 (16)	32 (8)	31 (8)
Rotation left (51)	39 (20)	40(10)	38 (10)
Hand-grip strength			
Right (51)	39 (20)	36 (9)	42 (11)
Left (51)	24 (12)	20 (5)	27 (7)
NME			
Ventral (48)	63 (30)	58 (14)	67 (16)
Dorsal (50)	82 (41)	88(22)	76 (19)
Static and dynamic balance			
Sharpened Romberg's test (49)	37 (18)	38(9)	36(9)
Walking in a "figure –of – eight" (46)	35 (16)	36(8)	33(8)

* Participants results on clinical tests are matched to reference values matched for age and sex obtained from healthy individuals. Impairment is presented in individuals (number and percentages) with scores lower than -2SD in cAROM and hand-strength or 10th percentile in NME and balance tests of the mean or median values for references.

CP= Cloward Procedure, CFIC= Cervical intervertebral fusion cage

cAROM= active range of motion, NME= Neck muscle endurance

Qualitative findings (paper IV)

Women's experiences of daily life 1.5 to 3 years after ACDF surgery were described in five different ways as outlined in Table 8.

Table 8. Overview of categories and sub-categories on women's experiences of daily life after anterior cervical decompression and fusion surgery.

Categories	Sub-categories
Experiences of recovery	<ul style="list-style-type: none"> • Experiencing daily life as restored or improved • Experiencing positive feelings related to surgical outcome • Experiencing a functional everyday life despite symptoms • Experiencing own life as limited • Experiencing being a different person with symptoms or without
Experiences of symptoms in daily life influence feelings and thoughts	<ul style="list-style-type: none"> • Describing remaining symptoms • Negative or positive feelings related to symptoms • Thoughts about causes of remaining symptoms – medical or own behavior • Expectations and hopes of a future without symptoms
Making daily life work	<ul style="list-style-type: none"> • Making adjustments to and in activities to make life work • Behaviors and techniques to reduce neck-problems • Choosing strategies of the mind • Experiencing a need for new treatment or altered behaviors
Experiencing the importance of social and occupational networks	<ul style="list-style-type: none"> • Family situation creating calm or tension • Participating in social and domestic life positively affects daily life and well-being • Conditions for return to work
Experiences of the influence of healthcare professionals and interventions on daily life	<ul style="list-style-type: none"> • Experiences of medical and rehabilitation interventions to have positively influenced physical recovery • The actions, competence, and approach of surgeons and physiotherapists have influenced recovery, activities, and behaviors • Surgery-related complications affecting heart and throat negatively affecting daily life

Experiences of recovery

Experiences of daily life ranged from being recovered or greatly improved, being able to live a close to normal life despite disabilities, to being limited and greatly affected by the symptoms. Women experienced improvements in daily life compared to before surgery, and were able to do most things at home, at work and/or in social situations that they could not do before surgery. Positive feelings related to surgical outcome was also describes in the experience of being recovered or improved:

*“... I can do everything you know, shovel snow, walk to the store, carry heavy bags
/// without any pain so that, well, it is extremely positive it is ...” (I:7)*

Some informants described that they experienced remaining or recurring symptoms, but that they were able to perform most of daily activities despite these symptoms:

*“... I live my normal life because ... uhm ... I have, live with what's remaining if
you say so /// the pain and the other (neurological symptoms in the arm), mm so I
live like I used to ...” (I:11)*

Simultaneously with experiencing improvements in daily life, most informants also described their lives as limited compared to a normal, preferred, hypothetically normal life. These limitations included necessary activities as well as recreational activities:

*“... it's no ordinary life this for me it's not...I've been used to working you know
...” (I:4)*

Experiences of symptoms in daily life influence feelings and thoughts

Informants experienced residual or recurrent neck-related symptoms such as pain, stiffness, weakness and sensory disturbances. The remaining problems could be accompanied by mostly negative feelings of anger, sadness, and worrying about a deterioration of symptoms:

*“... now when I know that this is as good as it gets ... I'm a bit, or very much sad
about ... how much pain I'm in today...” (I:13)*

Thoughts about causes of persistence and the future were also described:

*“... how the vertebrae around (the segment operated on) will manage my working
on the computer /// wonder whether it will hold up for a few more years “ (I:3)*

Making daily life work

Informants described that within daily life, strategies and adjustments were implemented to make occupational, domestic, and social areas work. Adjustments were made by performing the usual activities somewhat differently or by choosing alternate activities:

“... I don’t do it all at once like before /// and I don’t do it as fast ...” (I:5)

Mental strategies described by the informants were; thinking positively about life or ignoring pain in certain social situations in order to increase well-being and to be able to participate.

Strategies were also developed to control physical symptoms by either reducing or avoiding triggering the symptoms in order to diminish their impact on daily life. Active strategies to control pain on a daily basis were to engage in physical activities and/or perform mobility or strengthening exercises. Medication and relaxation techniques, rest, and social withdrawal were strategies used when the pain worsened:

“... because the more I move around, the less ... the less problems I have with my neck...” (I:11)

“... much of it is about reducing the pain uh pain medicine and then lay down on the floor, relax /// further ... this meditation tape // it has helped me very much...” (I:9)

Experiencing the importance of social and occupational networks

Family was most often described as supportive. Participating in social and occupational activities influenced the informants’ well-being and daily life by increasing positive energy, diverting attention from a tough situation, and creating a sense of belonging:

“...it’s important I think that you have the social (life) because otherwise I probably wouldn’t manage ... /// ...think it is important to not sit at home feeling sorry for yourself but try to get out ...” (I:5)

The return-to-work conditions were also important for being able to participate in occupational life.

Experiences of the influence of healthcare professionals and interventions on daily life

Informants described the treatments and support from healthcare professionals as positively influencing daily life by facilitating physical recovery, as well as providing confidence, individualized treatment, information, and advice. Physiotherapy treatment and physical training were described as facilitating recovery by improving neck and arm function as well as functioning at work and in psychosocial aspects of life:

“... the pain ... it can’t compare at all to how it was before surgery /// that has changed ...” (I:8)

“... physiotherapy it helped as well /// to get in shape and that’s both mentally, socially and physically ...” (I:8)

DISCUSSION

The overall aim of the thesis was to evaluate long-term functioning after anterior cervical decompression and fusion surgery due to cervical disc disease, and to provide new insights into patients' experiences of daily life after surgery.

This study is unique in that it is a 10-14 year follow-up after both the Cloward procedure and the Cervical Intervertebral fusion cage (CIFC) technique, and that the evaluation includes both patient-reported outcomes from a biopsychosocial perspective, clinical measures of physical function, and the patients' perspective on daily life after surgery.

Main findings

The main results of this thesis show that there were no between-group differences in long-term pain or disability after Cloward Procedure compared to the CIFC. Secondary outcomes were, with a few exceptions similar. Neck-related pain decreased after surgery and remained improved from the 2-year to the 10-year follow-up. Disability ratings however, did only remain improved in the CIFC group. Predictors of a successful outcome in neck-related pain intensity were high preoperative neck-related pain intensity (Odds Ratio 1.06) and non-smoking (Odds Ratio 3.03). Male gender was the only predictive factor of a successful outcome in neck-related disability (Odds Ratio 4.33).

Global outcome, health-related quality of life, catastrophizing, self-efficacy and perceived control over pain were factors that differed between individuals with a successful outcome or without. Such factors also correlated significantly with the 10-year outcomes of pain and disability.

Moderate to severe pain and patient reported disability was seen in half of participants at this long-term follow-up, and neck-related physical impairments were seen in between 18 (cervical flexion) and 82% (NME dorsal).

Daily life was experienced as recovered or improved by women after ACDF surgery. Despite these improvements, they were simultaneously affected and limited by remaining symptoms. Behaviors and activities in daily life were consequently altered to adjust to the symptoms. Social support provided by family, social and occupational networks, and from the healthcare professionals were experienced as important in a good daily life.

Discussion of the results

Comparisons between treatment groups

There were no differences in main outcomes of neck- or arm pain, self-reported disability or neck-related physical function between the two treatment groups. These results are similar to earlier follow-ups of solely patient-reported outcomes from the same study (10, 105), and to other studies with shorter follow-ups comparing other cage techniques with the Cloward Procedure (7).

No previous studies have compared outcomes of physical function between these two, or other, surgical techniques as was a part of this study. Better long-term physical and self-reported functioning in the CIFC group could have been expected due to the theoretically more durable graft compared to the Cloward Procedure using only autologous bone (10). Graft subsidence has been proposed not to influence 1 outcome at 5-year follow-up (126).

In the present study, the lack of statistical differences between groups may be influenced by small sample sizes of and large variability within sub-groups. When performing additional analyses of sub-groups based on fusion status (fusion status evaluated at 2-year follow-up), there were significant differences in pain and self-reported disability outcomes between individuals with or without healed fusion (healing status evaluated at 2-year follow-up) ($p = .02$). The influence of fusion on these 10-year outcomes is however unclear.

Follow-up over time

Pain ratings improved from preoperative to 2-year follow-ups in both surgical groups. There was no significant change in pain intensity after the 2-year follow-up and pain ratings remained significantly improved at 10-year follow-up. In the total group there was a significant improvement in patient-reported disability at 2-year follow-up, however this improvement did not remain at the 10 year follow-up in the group as a whole. When separate analyses of each treatment group were performed, the individuals in the CIFC group did have a remaining significant improvement from preoperative values to 10-year follow-up.

Two previous studies on pain and global outcome after ACDF with a more than 10-year follow-up were found (12, 13). These studies by Noriega et al. (13) and Faldini et al. (12) were both evaluations of the Cloward procedure and were at least partially retrospective follow-ups. These studies showed large reductions in pain over time, with long-term pain intensity outcomes scores of 2.0 and 1.0 (0-10 numeric rating scales). The present study evaluated ACDF at more than ten-year follow-up with both the Cloward procedure and an intervertebral fusion cage. As in the other studies, pain intensity was reduced over time in the present study, but the 10-year values of pain intensity were higher in the present study (group mean of 35 mm VAS) than in the previous studies.

Worse disability and pain intensity at 10-year follow-up in comparison with the 2-year follow-up could have been expected, due to an expected progressive degeneration of the spine caused by the course of the degenerative disorder, or of adjacent segmental levels degeneration after the surgical procedure (52, 53).

Also, 85% of the participants reported good effect of surgery (better, much better, and complete relief on the global perceived effect score) in both treatment groups, which is in line with other studies after ACDF (8). An important finding when evaluating the outcomes over time in this sample is that as many as 53% of the individuals had remaining or recurrent pain (> 30 mm VAS) and 52 % reported moderate or worse disability ($\geq 30\%$) at the 10-year follow-up with group mean values of 35 mm VAS and an NDI score of 29.

Predicting long-term outcomes

High preoperative pain intensity as a predictor of clinically relevant difference from preoperative values was also present in a 6-month follow-up after ACDF using dichotomous outcomes based on pain intensity change score (11). High preoperative pain ratings was an expected predictor of a successful outcome since MCID in pain intensity was used as a cut-off, both due to the construct of MCID but also as a construct of the VAS measure itself. Perhaps the result that preoperative NDI ratings did not predict a successful outcome in neck disability was more surprising. One other study evaluating factors that predicted a clinically relevant difference on the NDI (defined as a >15 -point improvement) from preoperative to 2-year follow-ups (63) showed that a higher preoperative disability level was a predictor of a positive outcome. The change in 10-year disability ratings could possibly be more influenced by psychosocial factors, and pain intensity more influenced by the surgical procedure.

Non-smoking status and male gender as predictors of a successful outcome in pain intensity and NDI, respectively, are consistent with earlier (2- and 6-year) findings of the same study population (66, 67). A trend toward a poorer global effect of surgery in smokers compared to non-smokers was also found in a study with 2 year-follow up (8). Smoking has also shown to be a risk factor for lumbar disc disease (127). Male gender as a significantly predictor of a successful outcome using bivariate analysis in other research on patients after cervical surgery using the Cloward Procedure (65).

The lack of a strong model predicting a successful outcome after ACDF surgery may indicate that other physical or psychosocial factors are important for outcome at long-term follow-up. Preoperative psychosocial status has shown to be an important factor of outcome on lumbar spine surgery at 6 months and 2-3 year follow-ups (73, 128). In the present study, there was, unfortunately, no assessment of participants' psychosocial status, either preoperatively or at early follow-ups.

Results from the 6-year follow-up of the present study showed that early follow-up outcomes better explained the 6-year outcomes than did preoperative factors

(67). Evaluating the predictive value of short-term radiological data, functioning, and personal factors on 10-year outcome would be an interesting approach for future studies.

Gender differences

In this thesis, gender differences were apparent in functioning and psychosocial factors. Women had significantly worse pain, patient-reported disability, catastrophizing, self-efficacy, and fewer women had a successful outcome on the NDI. Interestingly, there were no gender differences in ability to decrease or control pain, or in achieving a successful long-term outcome in neck-related pain. In addition, women had equal or better physical function (less impairments in ventral NME and dynamic balance) compared to men. It has been proposed that catastrophizing might account for the higher pain ratings in women (129) which could be the case in the present study. Since the included women had significantly higher preoperative pain intensity than men, the women were more likely to improve more than the MCID (improvement of 30 mm VAS), and be classified as successful outcome despite reporting worse pain at the 10-year follow-up. The gender differences in dynamic balance impairment was most likely due to larger feet in men, but the higher impairment rate in ventral NME for men is puzzling.

More gender-oriented research in order to improve the outcomes reported by women after ACDF is needed. The decision to only include women in the interview study was made in an attempt to achieve a better understanding of the daily lives of those with the worst reported outcomes.

Physical impairments at 10-year follow up

A large number of individuals had impairments in neck-related physical function. Only a limited number of studies have previously reported impairments in neck-related function at one-year (14, 115) and 3-year (17) follow-ups after CIFC (14, 115) and after cervical disc surgery with or without fusion (17). Balance impairments have previously been reported in two small experimental studies at short term follow-ups after surgery (15, 130).

Of the included measures of function, impairment rates were especially high in NME (82% extensors and 63% flexors). Reduced neck-muscle endurance and/or strength has been shown in individuals with other neck pain conditions (131) as well as in individuals with cervical radiculopathy and scheduled for surgery (132). Neck muscle function may be reduced due to altered neck muscle activity with increased activity of the superficial neck flexors (i.e. the sternocleidomastoid) and reduced deep flexor activity (133), and increased antagonist co-activation of both flexors (sternocleidomastoid) and extensors (splenius capitis) (134) in patients with neck pain. Strength may also be reduced due to structural changes of the muscles as hypotrophy (135) of the extensors.

In the present study, ventral and dorsal NME did correlate to pre-test neck pain, but only moderately ($\rho = - .43$ and $.52$), and the participants rated significantly ($p = < 0.001$) higher pain immediately after the NME testing than before. These findings raise the question if the NME test used in this study was a true test of endurance with fatigue ending the test, or if pain was the reason why individuals stopped. Both pain and/or neck-muscle fatigue may have an impact on muscle function and neck-stability in daily life and from this perspective, the NME test measures function of the neck. Other factors that possibly interfere with a “true” result of muscle endurance are pain tolerance, motivation, fear of test-induced pain, neck-mobility and muscle coordination.

The outcome most likely to be reduced by the surgical procedure was cAROM, due to fusion and segmental loss of mobility. In the present study, mobility was most affected in rotation and lateral flexion. Approximately 40% of cervical rotation occurs at the atlanto-axial joint (20) and the participants had surgery at the lower cervical segments, which make the large impairment rates in rotation surprising. Passive cervical ROM at 3-12 months follow-ups after surgery has been shown to increase compared to preoperative results, but to remain worse than the results of healthy individuals (69). Similar to those short term results of passive cervical ROM (69), the cAROM in the present study was not correlated to the number of segments operated on, indicating that ROM is not reduced only by the segmental loss of mobility. The impaired long-term ROM after surgery may also be due to adjacent segment disease after surgery (136), or to the progressive nature of cervical degenerative disc disease which could have affected other segments of the cervical spine over time (52).

Over the years, both neck-muscle endurance and cervical mobility might have been influenced by factors other than those directly related to the surgical procedure and the degenerative process. In addition to the ongoing degenerative process, perhaps the impairments found in these individuals could be caused in part by chronic or recurrent pain, or from fear of movement and avoidance behavior after surgery causing a disuse syndrome and deconditioning of the cervical spine and muscle function. The interviewed women (paper IV) described avoidance behavior due to the fear of re-injury as a strategy in daily life. Fear of movement ratings equal to those of individuals with chronic pain have been seen in individuals after cervical or lumbar surgery due to degenerative conditions (137). Additionally, early postoperative fear of movement was a significant predictor of high pain intensity and disability as well as low physical health at 6 month follow-up after spinal surgery (138). The impaired hand strength and balance may also be due to under-use and deconditioning of the muscles of the hand and the postural control systems respectively.

Since neck-muscle fatigue (139) and neck pain (140) has shown to influence sensorimotor function and postural control, these outcomes were expected to correlate with poor balance performance. However, there were no significant correlations between pain and neck-related physical function to balance. Perhaps

if other functions such as joint positioning sense, or morphological changes to the neck-muscles would have been assessed, these scores would have correlated to balance performance.

On a group level (mean age 59) the participants had cAROM scores similar to those of healthy age groups of 70-97 (depending on plane of mobility). The balance scores were similar to those of 70-79 year old healthy individuals. In hand-grip strength and NME, the participants' scores were worse than the reference values of the oldest age groups of healthy individuals. These neck-related impairments might limit many activities in everyday life, however the poor balance at a younger age may be the most complicating. Starting out with poor balance combined with the decline in neuromuscular, visual and vestibular systems that usually occur with increasing age, could result in increasing balance difficulties later in life, with inactivity and falls as a consequence.

Exercise programs targeting the strength and/or endurance of neck-muscles have shown to improve cAROM and neck muscle function as well as pain and disability ratings in patients with chronic neck pain (141, 142). Perhaps long-term neck-related functioning would improve if a more extensive rehabilitation program, with neck-specific exercises and a cognitive approach, was offered to patients postoperatively and in times of recurrent pain. Results from a recent study show that patients improved after a 3-month specified rehabilitation program, however they still exhibited some physical impairments at a 2 year follow-up (16).

Along with neck-related physical impairments, only about half of the participants in the present study had improved beyond the MCID in pain intensity (VAS), and only one third in NDI. Also, 53 and 52% of the participants who responded to the questionnaires reported moderate or worse pain and disability at 10-year follow-up. These findings of remaining disabilities are contradictory to the reported successful effect of surgery (85%), and the significant reductions in pain over time.

Women's experiences of daily life

The contradictory reports of being improved after surgery and at the same time experiencing remaining activity limitations, pain and other symptoms expressed in the interviews (paper IV) were similar to the quantitative findings. Positive feelings, such as happiness and thankfulness related to surgical outcome were expressed by the informants. Such factors may influence a global perceived effect (recovery) score, but do not necessarily describe good functioning or a good daily life. The results of the present study are in line with a previous study which showed that pain reduction was the strongest influence on satisfaction with ACDF surgery (143). Patients' ratings of effect of surgery after ACDF has also been proposed to overestimate positive results (144), indicating that an accurate evaluation of the extent to which the patients' problems are resolved by surgery requires questions regarding symptoms rather than only one general outcome score.

The use of strategies to master pain and to make adjustment in daily life appeared as one pattern in the interviews. Cognitive and behavioral efforts to manage activity limitations and existing symptoms, or to prevent symptoms can be interpreted as examples of coping strategies (145). Active and passive coping strategies are differentiated by the locus of control of the strategies. Coping is considered as active when one's own resources are used to control pain and to function despite pain (146), and passive when one is experiencing helplessness, relies on others for pain control, or allows pain to adversely affect other areas of life (146). Passive coping strategies, and especially catastrophizing, have been associated with a poor outcome of pain conditions (73, 147). In the results of this thesis, there was a significant difference in catastrophizing between individuals with and without a successful outcome on the NDI (paper II), however catastrophizing was not expressed by the interviewed women.

The women described using active strategies to control pain continuously and in all areas of daily life. When the pain intensified, the informants turned to passive strategies for pain control. This is in line with theories stating that active strategies tend to be used when the stressor (pain) is considered a challenge, but when the stressor is considered harmful or threatening, passive strategies are used (148). Catastrophizing was not expressed in the interviews, however some of the negative feelings related to the experience of symptoms can be considered passive coping, i.e. worrying about a deterioration of symptoms. To make daily life work, the women also described scaling down activities, and to change activities (domestic, leisure and occupational) from more to less demanding in order to function in daily life despite symptoms.

In addition to providing a better understanding of the experience of recovery, symptoms, activity limitations, and coping strategies, the qualitative findings also revealed the importance of social support for the experience of daily life after ACDF surgery. No previous study has investigated the aspect of environmental factors and more specifically social support in outcome after cervical spine surgery. The women experienced that social support from family and friends, occupational networks, and from the healthcare system as important in managing and having a good daily life. The importance of social support from these three arenas, private, occupational and healthcare, was also identified in patients with musculoskeletal disorders in a rehabilitation setting. Both the practical support (such as the interventions), but also the informational and emotional support from healthcare professionals were experienced as important for their current daily lives.

The qualitative results are clinically important in that they emphasize the need to understand a patient's complete situation, in order to promote a successful outcome, and to understand the importance of patient-provider communication. However, further research is needed to evaluate the effect of negative feelings, coping strategies, and social support on the experience of recovery, and pain and disability outcomes. Also, interview studies on men similar to the present are

needed to make findings more transferable, or to identify potential differences between men and women in experiences of daily life after ACDF surgery.

Methodological discussion

Using the ICF classification, the outcome measures used in the thesis encompass both functioning and contextual factors. For descriptive purposes, the actual scores of overall health, functioning (or disability) evaluated as body function (pain ratings, physical function), activity limitations and participation restrictions (NDI, impact on daily life ratings), and also personal factors (gender, age, coping and self-efficacy) were evaluated. Women's experiences of daily life were linked to both body functions, activities of daily life, participation, personal factors (coping strategies) and environmental factors (work, social support and the healthcare professionals) were domains related to their experiences. By combining quantitative and qualitative approaches, and thus illuminating the research question from different perspectives, this study provides an increased understanding of the health condition of individuals after ACDF.

The lack of preoperative and/or early postoperative data on physical function and personal factors such as coping strategies, self-efficacy and fear of movement hinder the possibilities to evaluate physical function over time, or to analyze the impact of psychosocial variables on main outcomes over time, which would have added valuable information to the thesis.

Quantitative methodology

A few considerations regarding main outcome measures also need to be noted. The first consideration regards measuring pain intensity. Neck-related pain was the one pain intensity measure evaluated in the original study, and it was impossible to evaluate neck and arm pain separately over time. Separate ratings of axial (neck) and radicular (arm) pain are however, recommended after cervical spine surgery (5). In the cross-sectional analysis of 10-year data, both neck and arm pain ratings in addition to general neck-related pain were included.

One of the disadvantages of VAS compared to a Numerical Rating Scale (NRS) stated in the literature is that VAS is not as comprehensible and less preferred by patients which may lead to more missing and incomplete data (82). In the present study, all participants completed VAS ratings of neck-related, neck and arm pain, and headache. The VAS however, is a more robust measure than the NRS and may be analyzed using parametric statistical analysis if the data is normally distributed (149)

Recently, the NDI has been questioned as the gold standard disability outcome measure in individuals with cervical radiculopathy. The Cervical Spine Outcome Questionnaire has shown to have superior responsiveness compared to the NDI,

and to be valid and reliable in individuals after cervical spine surgery (150). Nevertheless, the NDI remains the recommended measure after cervical spine surgery (5, 6) and NDI scores are possible to compare between studies.

All measures of physical function were controlled by the patients and perhaps such factors as fear of test-induced pain and lack of motivation reduced the participants' performances causing low test scores. The NME test is a "maximum" test in the sense that individuals are instructed to stay in a position for as long as they can. The question arises if the test of NME used in this study was a true test of endurance with fatigue ending the test, or if pain was the reason why individuals stopped. In this study it was possible to test the correlation NME to pain, but not to other factors. Pain and/or neck-muscle fatigue has an impact on muscle function and neck-stability in daily life and in this perspective the NME test measures function of the neck. Other factors that most possibly interfere with the "true" muscle endurance of either muscle group tested are pain tolerance, motivation, neck-mobility and muscle coordination. One individual was unable to perform the ventral test due to inability to perform upper cervical flexion. Studies have found mechanical activation of both deep and superficial ventral and dorsal neck-muscles when performing the ventral and dorsal NME test respectively (151).

When using MCIDs to classify outcomes as successful or not, the values chosen should preferably be derived from studies with the same population and intervention. At the time of data collection and analysis of this thesis, no MCID values were published on patients after ACDF surgery. The MCID value in VAS for pain intensity was based on a study of rheumatic patients undergoing a corticosteroid injection for pain relief (86). In NDI, the MCID was based on patients with mechanical neck pain, both with and without arm pain, after physiotherapy intervention. In these patients, the statistically detected change score was larger than the anchor based and therefore, the larger value was used as a threshold in the thesis. A fairly new study by Parker et al. (78) on individuals 3 months after ACDF for degenerative disc disease presented a MCID of 17.3% on the NDI using a patient satisfaction scale as an anchor. These MCID values indicate that the score change of 20 in NDI used in this thesis could have been too large. The study by Parker et al. (78), also presented a MCID value for neck pain as a 2.6 point change on a NRS, but no MCID values for pain intensity using the 100 mm VAS.

The low rate of patients reporting a successful outcome in the present study may reflect this high cut-off level for defining MCID in pain and disability. It has been speculated that when patients have high preoperative pain ratings, a larger change score is needed for patients to perceive some relief after intervention (152). The high preoperative pain levels (Mean 69 mm VAS, range 15-100) in most of the individuals in the thesis support the use of a large MCID value in pain ratings. However, the sample included in the thesis are individuals with a degenerative disc disease more than 10 year after surgery and because of this, a 30 mm pain reduction

and a score change of 20 in NDI could be too large. Using absolute change in pain (i.e. mm pain) to determine successful outcome has previously been proved highly dependent on baseline pain (86), indicating perhaps that the use of a percent change score could have been better. High baseline pain was also a predictor of successful outcome in this thesis, and perhaps a 30% (82) or 50% (86) change in pain and disability scores could have been more accurate as outcome in the logistic regression. There were significant differences in ratings of pain, other symptoms and disability between improved and not improved individuals, which strengthens the use of the chosen MCID values to use as thresholds for defining a successful long-term outcome after surgery.

Qualitative methodology

During the research interviews, a semi-structured interview guide was used to allow informants to express their own understandings in their own terms. Using an interview guide may however involuntarily omit topics not identified in the guide. Due to this risk, the last question in the interview guide was: “Is there any additional information you would like to tell or describe that is related to your experiences of daily life after neck-surgery or to your neck symptoms?”. This last question allowed the informants to express any experiences not asked for during the interview, or to further add to previous descriptions.

Inductive content analysis of the manifest meaning of the interviews was performed. Content analysis allows the patients to be in focus, not the phenomenon. Inductive analysis was used to stay open to the patients’ perspectives and to explore their experiences.

In qualitative research there is a trade-off between collecting shallow information from a larger number of informants and more in-depth understanding of a smaller number of informants (79). The inclusion of the qualitative interview study was based on the concept of redundancy, and inclusion ended when no new information was provided by including new informants (79). Maximal information on the research question was thus made possible, and the analysis was based on rich information from a group of women after ACDF surgery.

Limitations

One limitation to this study are the small sample-sizes, due to the large amount of drop-outs from original inclusion (n=95) to the study of physical function in which only 51 of the original 95 individuals participated. In the studies based on questionnaires, 73 of 95 individuals (77%) were included which can be considered as satisfactory with regard to the long follow-up time. The small number of participants limits the results in two ways.

First, small sample sizes in a RCT increases the risk of type 2 error of wrongly retaining the null hypothesis. The original randomization was based on arbitrarily set differences in the main outcome of neck-related pain intensity (15 points VAS)

between groups, and on the variability of preoperative values, and samples sizes were determined to be adequate at 41 individuals per group. The variability and standard error of measurement of the clinical measures (predominantly NME) in healthy individuals have been shown to be large, indicating the need of even larger sample sizes to reach adequate power. Thus, the functional outcome might differ between groups, but the groups are not large enough for any statistical changes to be detectable. The results of no differences in self-reported pain, disability or global outcome between surgical methods are in line with previous studies and these similarities combined with the relatively larger samples, relative to the functional study, these results can be thought of as strong despite somewhat too low sample sizes.

Second, the large number of drop-outs from original inclusion might diminish how representative the remaining individuals are of the original sample, thus compromising the generalizability of the results to the whole population. There was a difference of 10 mm preoperative VAS between individuals not responding the questionnaires and who did, this 10 mm VAS mean difference was also present when comparing the participants in physical function tests with those not participating. This group difference was not significant and there were no differences in preoperative NDI or radiological findings. Also, the only differences in patient-reported outcome at 10 year follow-up between those participating in the measures of physical function and who did not were worse health related quality of life in the group not participating in the tests. This indicates that the impact of the drop-outs on the results is negligible, and that the participants are representative for the group as a whole.

Another limitation to the study is the lack of radiographs at the long-term follow-up. Even though the included studies aimed at evaluating functioning and daily life as rated or described by the patients, radiographs could have provided information on adjacent segment disease, and possible newly developed myelopathy, thus providing a more comprehensive base to relate the self-reported and clinical findings of pain, disability, neck-related physical function and balance. Before each individual's test session, as a safety measure, questions regarding symptoms of myelopathy were posed to the participants. Balance performance could also possibly be influenced by vestibular or other sensory impairments. These functions were not evaluated in this study.

Despite limitations this study provides new information on long-term self-reported and clinical pain and functioning. No other long-term follow-ups have evaluated and described outcome of surgery using a broad set of measures covering the dimensions of the ICF, including body functions, activities, participation, and environmental and personal factors.

CLINICAL IMPLICATIONS

- Despite the performed decompression and stabilization of the cervical spine, individuals with cervical degenerative disc disease still have substantial problems and disability at long term after surgery, with a potential need of continuous treatment.
- The descriptive findings of physical function may add to an increased understanding of the long-term outcome in patients after ACDF without a structured postsurgical rehabilitation program
- Finally, results on long-term functioning as well on how individuals experience and cope with daily life provide knowledge on patients after cervical spine surgery not previously described. These findings may provide a basis for better management after cervical spine surgery due to degenerative disc disease intended to enable good long-term functioning.

CONCLUSIONS

The patient reported outcomes of ACDF either by the use of the Cervical Intervertebral Fusion Cage (CIFC) or Cloward Procedure were similar at 10-13 year follow-up and over time. Pain intensity improved more than disability, indicating that perhaps additional interventions may be needed for better functioning. Neck-related pain intensity was significantly improved at follow-up of 10 years, but that the initial reduction in neck-related disability (10) did not last at 10-year on a group level.

The variables identified as predictive of a “successful outcome” in pain intensity and neck-specific disability 10–13 years after ACDF were high preoperative pain intensity, non-smoking status, and male gender.

More individuals had a “successful outcome” in pain intensity than in disability, and psychosocial factors differed to a larger extent between unimproved and improved participants in disability. Women had worse outcomes than men in patient-reported outcomes, were more influenced by negative psychosocial factors, but men had worse impairment rates in ventral NME and dynamic balance.

There were no differences in physical function scores or impairment rates between the CIFC and the Cloward Procedure at this 11 to 14 -year follow-up. Neck-related physical impairments, especially in NME were present in a large percentage of this group of individuals. Neck-specific physical function and hand function but not balance performance were statistically associated with pain.

While improved after surgery, most informants experienced remaining symptoms and limitations in daily life after ACDF surgery. A variety of mostly active coping strategies were used to manage daily life. Social support received from family, friends, occupational networks, and healthcare professionals, positively influenced daily life.

In summary: pain, physical function and patient-reported disability were similar between the two ACDF techniques, at the more than 10 year follow-up and over time. High preoperative pain intensity, non-smoking and male gender predicted a successful long-term outcome. Individuals after ACDF surgery experienced improvements in pain intensity and a good effect of surgery although they simultaneously reported remaining disability

FUTURE RESEARCH

- Future studies are needed to explore whether an intervention of a structured rehabilitation program after surgery can improve functioning more than ten years after ACDF.
- The influence of psychosocial factors over time was not possible to evaluate due to the lack of such assessments preoperatively and at short-term follow-ups. Including factors such as beliefs, coping strategies and self-efficacy in future prospective studies could be recommended.
- It is likely that many individuals recover by the surgical intervention alone, but some individuals might need more support to manage and control symptoms, to improve physical function, and to experience a good daily life. It would be of clinical interest in to identify preoperative characteristics, or early postoperative outcomes, that predict who would be likely to benefit from a personalized and structured rehabilitation program.
- Future research should also focus on how men experience and describe their daily life and outcomes after ACDF, and potential differences between men and women.

SUMMARY IN SWEDISH

Disksjukdom i nacken med nervinklämning kan vara ett besvärande tillstånd med utstrålade smärta till armen/armarna, känselbortfall och svaghet i armen, samt nacksmärta. Hos den största delen av patienter med nervinklämning i nacken läker besvären ut på 4-6 månader. Operativ behandling kan behövas när utstrålade smärta och neurologiska bortfall kvarstår trots icke-operativ behandling (smärtlindring, sjukgymnastik osv.). Det finns i dagsläget inga vetenskapliga bevis för vilken som är den bästa icke-operativa behandlingen, och det finns inte heller bevis för att operation är bättre än rehabilitering på lång sikt. Operation med främre teknik som innebär att diskmassa och benpålagringar i nacken som trycker på nerver tas bort, i kombination med steloperation mellan två eller flera kotor är en ofta använd kirurgisk behandling. För att fylla tomrummet som uppstår mellan kotorna när diskmassan tas bort, och för att skapa stabilitet runt operationsområdet, kan benmassa från höftbenskammen, eller burar av olika material användas. Teoretiskt sett förväntas användandet av en bur förstärka operationsområdet och minska risken för återkommande problem. I dagsläget finns inga vetenskapliga bevis för att ett material (bur jämfört mot enbart benmassa, eller olika burmaterial jämförda mot varandra) är bättre än något annat avseende patientskattade utfallsmått efter operation, men detta har inte följts upp över längre tid hos patienter.

Utfallet av operation är oftast fördelaktigt med förbättrad funktionsförmåga, minskad smärta, och operationen skattas oftast som effektiv av patienter. Tidigare studier har visat att män har större chans att få bättre utfall av operationen, men det finns i dagsläget ingen kunskap om hur och vilka utfallsmått som skiljer män och kvinnor åt före och efter operation. Resultaten av ett fåtal mindre studier som har utvärderat funktionsförmåga har funnit att en relativt stor andel patienter har nedsatt självskattade och kliniskt uppmätt funktionsnedsättningar efter operation. Ingen av dessa studier har utvärderat funktionsnedsättning mer än 3 år efter operation. Psykosociala faktorer är dåligt utforskade. Inga studier finns i dagsläget som utvärderat patienters perspektiv på dagligt liv efter nackoperation.

Det övergripande syftet med avhandlingen var att utvärdera funktionsförmåga efter steloperation av halsryggraden med två sorters främre tekniker; med och utan bur, över tid och i relation till nackfriska individer. Syftet var även att vidga förståelsen för faktorer som påverkar utfallet av operation, samt ökad förståelse av kvinnors upplevelser av sitt dagliga liv efter nackoperation.

Avhandlingen innehåller en långtidsuppföljning (minst 10 år) av en tidigare studie, där initialt 95 patienter deltog. Dessa lottades till en av två olika tekniker

av steloperation i halsryggraden med främre teknik. Vid uppföljning, efter minst 10 år, deltog 77 individer som besvarade enkäter avseende smärta, funktionsförmåga, psykosociala faktorer och hälsa. Utvärdering av nack-relaterad funktion utfördes på ett antal frivilliga deltagare (51 individer) ur enkätstudien och jämfördes med friska. Avhandlingen innehåller även en utforskande, kvalitativ, del där kvinnliga informanter deltog i individuella intervjuer i syfte att undersöka deras upplevelser av dagligt liv efter operationen.

Resultatet av studien visade att det inte förelåg några skillnader i långtidsutfall mellan operationsmetoderna vare sig gällande enkätsvaren eller den nack-relaterade funktionen. Patienterna hade fortsatt minskad smärta vid 10 år, men funktionsförmågan var endast förbättrad i den gruppen som opererats med en bur. Kvinnor hade sämre utfall än männen i självrapporterade mått, men hade inte sämre uppmätt funktionsnedsättning. En hög smärtskattning före operationen, att inte röka och vara man var faktorer som förutspådde ett bra utfall av operationen. En relativt stor andel deltagare hade nedsatt nack-relaterad funktionsförmåga. Intervjuerna visade att de inkluderade kvinnorna kände sig förbättrade av operationen, men att de samtidigt upplevde kvarvarande smärta och besvär från nacken som begränsade dem och gav upphov till förändrade beteenden i vardagen. Socialt stöd av familj, vänner, arbetsrelationer och från hälso- och sjukvårdspersonal var viktigt för att uppleva ett bra dagligt liv.

Slutsatsen av studien är att det inte var några skillnader mellan de två operationsmetoderna. Smärtan var betydligt mindre än den var före operationen och operationen upplevdes som effektiv, men trots det hade en relativt stor del av deltagarna kvarvarande funktionsnedsättning och påverkan på dagligt liv.

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