

# Restoring Upper-Limb Function Following Cervical Spinal Cord Injury: Current Practice in the United Kingdom

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## ABSTRACT

**Objectives:** Cervical spinal cord injury (CSCI) is a devastating consequence of trauma that results in disabling loss of upper-limb function. Functional reconstruction through surgical intervention can improve quality of life, reduce long-term care needs, and is highly rated by patients. Internationally, limited information exists on the number of patients eligible for surgical intervention, procedures undertaken, and provision of services. Our objective was to answer these questions to inform service developments in the United Kingdom (UK) and abroad. **Methods:** A postal questionnaire survey was distributed to the clinical leads of each of the 12 UK and Republic of Ireland spinal cord injury centres (SCICs). Information was requested on the local CSCI caseload, referral of CSCI patients to reconstructive upper-limb services, and surgical procedures undertaken locally during defined periods. Nonresponders were followed up with freedom of information requests. **Results:** Eleven SCICs responded (response rate: 92%) with a mean of 49.6 any-level CSCI patients admitted annually (>C5: 27.9 patients, C5/6: 18 patients, <C6: 6.5 patients). No SCIC reported referring CSCI patients for nerve transfer or awareness of any peripheral nerve service. Five SCICs stated that they referred CSCI patients for surgery to restore upper-limb function. **Conclusions:** Surgery to restore upper-limb function following CSCI is still developing in the UK. Provision of services to this small but deserving group varies regionally. Clinical expertise is limited to a handful of SCICs where surgeons perform tendon-related procedures. No SCIC reported undertaking nerve transfer surgery. Assessment of upper-limb function should be a standard of care for functional reconstruction of CSCI with awareness of surgery among health-care professionals and patients raised.

**Keywords:** Cervical spinal cord injury, functional reconstruction, nerve transfers, service development, spinal cord injury centers

## INTRODUCTION

Cervical spinal cord injury (CSCI) is a devastating consequence of trauma that afflicts 1 in every 29 adult major trauma patients<sup>[1]</sup> resulting in disabling loss of upper- and lower-limb function. Those affected endure reduced life expectancy, altered quality of life, significant morbidity, and long-term dependency.<sup>[2,3]</sup> In the United Kingdom (UK) and Republic of Ireland (EIRE), rehabilitation is undertaken within designated spinal cord injury centres (SCICs) where patients receive intensive multidisciplinary rehabilitation led by spinal injury physicians. Rehabilitation aims to transition patients to the greatest practicable level of independent living and minimize long-term care needs.

One of the most effective ways to optimize a patient's independence is to maximize their upper-limb function. The importance of upper-limb function is recognized by patients who rate it above control of sexual, bladder, bowel

function, spasticity, and pain.<sup>[4-6]</sup> Historically, the International Classification for Surgery of the Hand in Tetraplegia<sup>[7]</sup> has guided the use of tendon transfer, tenodesis, and arthrodesis procedures to restore upper-limb function. However, increasingly, nerve transfers are advocated. Proponents argue that they present greater opportunities for functional gain over tendon transfer with restoration of prehensile grip, less postoperative morbidity, and limited or no sacrifice of donor function.<sup>[8]</sup> Selective nerve fascicle transfer has been undertaken by a number of surgeons internationally<sup>[9-23]</sup> and represents a promising adjunct.

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As UK-based upper-limb surgeons with peripheral nerve expertise, we wish to develop upper-limb services for CSCI patients but recognize provision faces a number of challenges. These include lack of geographically co-located services (hand surgery and spinal rehabilitation), limited surgical expertise nationally (particularly for nerve transfer), poor awareness of current expertise, and historic professional distance. To address some of these factors and inform future service developments, we undertook a postal survey of designated SCICs within the UK and EIRE. We hypothesised that access to reconstructive upper-limb services, particularly nerve transfer surgery, was limited to specialist centers and varied according to the region.

## MATERIALS AND METHODS

A postal questionnaire was distributed to the clinical lead of each UK and EIRE SCIC [Figure 1] in early 2015. Respondents were asked to detail the number of new traumatic SCI patients



**Figure 1:** The United Kingdom spinal cord injury centers. (1) Glasgow (Queen Elizabeth National Spinal Injuries Unit). (2) Belfast (Musgrave Park Hospital). (3) Dublin, EIRE (National Medical Rehabilitation Centre). (4) Southport (Northwest Regional Spinal Injuries Centre). (5) Oswestry (Midlands Centre for Spinal Injuries). (6) Cardiff (Welsh Spinal Injuries and Neurological Rehabilitation Centre). (7) Middlesbrough (Golden Jubilee Regional Spinal Cord Injury Centre). (8) Wakefield (New Pinderfields Regional Spinal Injuries Centre). (9) Sheffield (Princess Royal Spinal Injuries Centre). (10) Aylesbury (The National Spinal Injuries Centre). (11) Stanmore (Spinal Cord Injuries Centre). (12) Salisbury (Duke of Cornwall Spinal Treatment Centre). Taken from <http://www.apparelyzed.com/spinalunits.html> (Website now defunct)

managed between January 1 and December 31, 2014, according to the level of injury, outline the local provision of SCIC upper-limb services, detail surgical interventions undertaken for functional reconstruction locally (including outcomes), and outline local availability of nerve transfer for CSCI [Figure 2]. Before survey distribution each SCIC was contacted to explain the questionnaire rationale. SCICs that did not respond to the survey were re-contacted with the same questions formulated as a freedom of information (FOI) request.

## RESULTS

Three SCICs responded to the postal questionnaire survey, and further eight SCICs subsequently responded to the FOI requests. No response was received from one centre despite follow-up communication.

### Spinal cord injury centre admissions

For the study period, the mean number of any-level SCI and any-level tetraplegic admissions was 85.1 (range: 3–140, 11 centers) and 49.6 (range: 27–84, 9 centers), respectively, per SCIC. The mean number of admissions with a CSCI above C5, at C5/6, and below C6 was 27.9 (range: 10–63, 8 centers), 18 (range: 7–27, 7 centers), and 6.5 (range: 1–17, 7 centers), respectively [Figure 3]. The American Spinal Injury Association Impairment Scale categories for CSCI patients at admission and discharge are presented in Figure 4. The mean age of CSCI admissions (any-level) was 56.5 years (range: 52–63, 6 centers).

### Upper-limb services for cervical spinal cord injury patients

Six SCICs reported holding local clinics or referring CSCI

- Q1. How many patients with a new SCI were admitted to your SCIC during the period January 1, 2014–December 31, 2014?
- Q2. How many of these patients were tetraplegic?
- Q3-5. How many tetraplegic patients had a CSCI above C5, a CSCI with preservation of function at C5/6 and a CSCI below C6, respectively? What were the ASIA levels at admission and discharge for these patients?
- Q6. What was the mean age of all tetraplegic patients admitted to your SCIC?
- Q7. Does your SCIC refer tetraplegic patients to a specialist upper-limb or hand surgery service? If so, please state which patient groups (and/or injury levels) referred
- Q8. Please state the name and contact details of the clinician(s) that provide the specialist upper-limb or hand service input to your SCIC
- Q9. For those tetraplegic patients referred to a specialist upper-limb and hand service during the period January 1, 2012–December 31, 2014, what percentage have undergone surgical procedures to reconstruct upper-limb function? In particular, nerve transfer, tendon transfer, or other procedures?
- Q10. For those tetraplegic patients managed at your SCIC who do undergo surgical procedures to reconstruct upper-limb function, what functional and/or patient-reported measures do you use to assess outcomes?
- SCI: Spinal cord injury, SCIC: Spinal cord injury center, CSCI: Cervical spinal cord injury, ASIA: American Spinal Injury Association

**Figure 2:** Survey questions

patients to specialist upper-limb or hand surgery services. Three SCICs stated that they did not routinely or ever refer CSCI patients and two SCICs did not answer the questions posed [Figure 5]. Four SCICs reported their outcomes for patients referred to specialist upper-limb or hand surgery services [Figure 6].

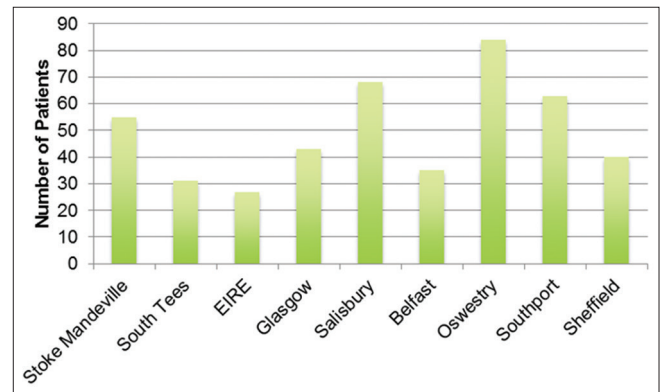
**Outcome measures**

Six SCICs employed outcome measures to assess surgical outcomes [Figure 7].

**DISCUSSION**

We find that CSCI accounts for nearly 60% of all admissions to the UK SCICs, with 50% of admissions representing C5–C8 level injuries. Comparative data relating to UK SCI incidence is difficult to obtain with no published national data currently available. This may change with the advent of the UK National Spinal Cord Injury Database ([www.spinalcordinjury.nhs.uk](http://www.spinalcordinjury.nhs.uk)). The high response rate (91.7%) of our survey means a snapshot assessment of annual CSCI workload can be extrapolated based on centre-reported response. We calculate annually that 596 patients within the UK and EIRE sustain an any-level CSCI and reach a SCIC including 294 C5–C8 injuries with varying levels of upper-limb function.

Following a CSCI, it is essential that every patient should have a detailed functional assessment of their upper limb by a specialist upper-limb surgeon; our survey shows that this does not currently occur. Upper-limb examination post-CSCI should not be an isolated event and should be repeated regularly by specialist physiotherapists during inpatient and outpatient follow-up. We strongly recommend that repeated documented clinical examination of the upper limb in CSCI should be integrated into the NHS



**Figure 3b:** Number of any-level cervical spinal cord injury admissions (January 2014–December 2014) according to the spinal cord injury center

	Mean number Admissions per SCIC
Any-level SCI	85.1 (3-140)
Any-level CSCI	49.6 (27-84)
CSCI >C5	27.9 (10-63)
C5/6	18 (7-27)
CSCI <C6	6.5 (1-17)

SCIC: Spinal cord injury center, CSCI: Cervical spinal cord injury

**Figure 3a:** Mean number of admissions according to the level of spinal cord injury per spinal cord injury centre

Level of CSCI	AIS	Admission (%)	Discharge (%)
>C5	A	21	18
	B	4	2
	C	44	29
	D	30	49
	E	2	2
C5/6	A	19	13
	B	10	11
	C	27	29
	D	41	45
	E	2	2
<C6	A	35	39
	B	3	2
	C	42	22
	D	35	57
	E	0	0

CSCI: Cervical spinal cord injury, AIS: American Spinal Injury Association Impairment Scale

**Figure 4:** American Spinal Injury Association Impairment Scale categories at admission and discharge

Referring centers	Nonreferring centers
<p>Stoke Mandeville</p> <p>“Any patients with hand problems seeking functional improvement, patients with contractures causing skin/splinting problems, general hand problems including arthritis and peripheral nerve entrapment (are seen by a local hand surgeon with a specialist interest)”</p> <p>South Tees</p> <p>“Patients with complete and incomplete tetraplegia between C5-C8 are referred for tendon transfer. All patients who may have hand problems due to SCI or carpal tunnel syndrome are referred”</p> <p>Glasgow</p> <p>“All tetraplegics”</p> <p>Belfast</p> <p>“Any patient with impaired upper-limb function is, if they wish, assessed at our combined rehab medical/orthopedic upper-limb clinic. Patients being considered for nerve transfer are referred to plastic surgery”</p> <p>Sheffield</p> <p>“We have a designated in-house service supported by physiotherapy and surgeons with specialist interest in reconstructive procedures.”</p> <p>Oswestry</p> <p>“All tetraplegic and paraplegic patients”</p> <p>EIRE: Republic of Ireland</p>	<p>EIRE</p> <p>“Not routinely”</p> <p>Salisbury</p> <p>“Not routinely”</p> <p>Southport</p> <p>“Currently, the center does not refer patients with tetraplegia”</p>

**Figure 5:** Availability of upper-limb services for cervical spinal cord injury patients

Center	Reported outcomes
South Tees	“All patients underwent surgery”
EIRE	“Tendon transfer” performed in a single patient (8 referred)
Sheffield	Surgery undertaken locally in 24 patients Correction of elbow or hand contracture (54%, n=13) Surgery performed Deltoid to triceps tendon transfer (17%, n=4) Tenodesis procedure (17%, n=4) Tendon lengthening (8%, n=2) Rerouting of biceps (4%, n=1)
Stoke Mandeville	Surgery undertaken locally in 146 patients by a single surgeon over 10-year period (2003-2013) 127 patients offered surgery: tendon transfers (n=92; 46% accepted) or other surgery (n=35; 94% accepted) Surgery performed Deltoid to triceps transfer (21 limbs, MRC 3-4 power in 90%) Brachioradialis to FPL transfer (26 limbs, useful grip in 92%) ECRL to FDPs (11 limbs, useful grip, 100%) Thumb intrinsic rebalancing (34 limbs) Finger intrinsic rebalancing (16 limbs)
EIRE: Republic of Ireland, ECRL: Extensor Carpi Radialis Longus, FDPs: Flexor Digitorum Profundus, FPL: Flexor Pollicis Longus, MRC: Medical Research Council	

**Figure 6:** Outcomes for patients referred to specialist upper-limb or hand surgery services by spinal cord injury centers over a 3-year period

commissioning criteria for SCICs. This change would improve rehabilitative practice by documenting the course of upper-limb recovery, elucidating surgical candidates, and focusing finite clinical resources on this important functional area. Mandating assessment by an upper-limb surgeon also provides scope for any appropriate surgical strategies (nerve transfers, tendon transfers, etc.) to be explored, discussed and considered by patients.

Our survey suggests that access to upper-limb surgery services following CSCI varies significantly with 25% of SCICs not offering any access – a concerning health-care inequality. Larger SCICs provide greater availability and hold specialist consultant-led clinics but this is very much dependent on a motivated surgeon locally. Confirmatory evidence is available from a recent British Society for Surgery of the Hand survey that identified only ten self-reporting hand surgeons undertaking upper-limb reconstruction for CSCI patients with only two having undertaken more than five cases annually.<sup>[24]</sup> Just four SCICs reported outcomes for patients who underwent reconstructive upper-limb surgery with tendon-related procedures mainly transfers being the mainstay intervention. No centres reported undertaking nerve transfer procedures – an unsurprising finding when expertise in peripheral nerve surgery is concentrated in specialist centres.

In light of the low number of patients and few SCICs that reported referral outcomes, it is difficult to draw conclusions regarding national practices, but it is clear that procedures performed varied between centers. The survey did not elucidate data on how patients were selected for

Centre	Outcome measures employed
Stoke Mandeville	Canadian occupational performance measure Sollerman hand function test Wheelchair function
EIRE	Patient-determined goals
Salisbury	Spinal cord independence measure
Oswestry	Clinical assessment
Sheffield	Canadian occupational performance measure
South Tees	Functional range of movement Goniometer measurements and videos Oxford hand score Sollerman hand function test Microprocessor upper-limb equipment
EIRE: Republic of Ireland	

**Figure 7:** Outcome measures employed by spinal cord injury centers following surgery

surgery and the functional gains prioritized, but the recent publication of the International Federation of Societies for Surgery of the Hand Scientific Committee on Nerve–Spinal Cord Injury Report – “Update on Hand Surgery in Tetraplegia”<sup>[25]</sup> – represents a useful guide for clinical assessment of CSCI patients. The document assists in surgical planning and goal prioritization making recommendations for interventional procedures (but excludes nerve transfer). We recommend that any surgeons asked to assess CSCI patients use this document to formulate treatment recommendations while being conscious of nerve transfer options. Those surgeons with an interest in nerve transfer should seek specialist training to increase exposure in addition to the current hand surgery curriculum.

Surgical uptake varied from 13% to 100% between centres. This is likely to represent variation in service access, surgical expertise, and depth and degree of counseling provided to patients regarding risks and gains of surgery. The decision for any CSCI patient to undergo reconstructive upper-limb surgery is highly influenced by how information is framed by health-care professionals. In similarity to the US, UK health professionals have intrinsic biases. At least one US questionnaire survey has documented discordance between professional groups (surgeons and physicians) on the utility of surgery. When asked whether “functional gains were worth the risk of surgery,” 73% of spinal rehabilitation professionals agreed or strongly agreed compared to 94% of surgeons.<sup>[26]</sup> When asked whether they “would want upper-extremity surgery,” 93% of spinal rehabilitation consultants agreed compared to 96% of surgeons. Pertinently, the study showed that spinal rehabilitation professionals were much more likely to favor reconstructive upper-limb surgery making 2.8-times more referrals with 13.1 more reconstructions undertaken where good relationships with their local hand surgeon existed.<sup>[27,28]</sup> This clearly demonstrates the importance of delivering reconstructive upper-limb surgery for CSCI within the confines of a spinal injury multidisciplinary team (MDT) and good working relationships.

## CONCLUSIONS

There is a scope for the development of reconstructive upper-limb surgery services, particularly nerve transfer within the UK, and it is hoped that this will act as a blueprint for service developments internationally. It is evident that upper-limb surgeons and spinal rehabilitation professionals need to work together and ensure that access does not vary geographically. This should aim to ensure that every CSCI patient receives an assessment of upper-limb function by an upper-limb surgeon working within a spinal injury MDT. Due to the limited number of upper-limb surgeons with expertise in peripheral nerve surgery, it is not pragmatic for all CSCI patients to be assessed by a peripheral nerve surgeon. Nonetheless, where such surgery may be beneficial, suitable patients should be referred for further assessment. We would encourage all hand surgeons to work with their local SCIC to raise awareness of the potential for reconstructive upper-limb surgery, in particular nerve transfer, for this small but very deserving patient group so that opportunities to improve functional outcomes are not missed.

## Recommendations

1. All CSCI patients should have a detailed clinical examination of their upper-limb function by a specialist upper-limb surgeon within a year of injury
2. Clinical examination of the upper limb in CSCI patients should be integrated into the commissioning criteria for SCICs and regularly repeated
3. All SCICs should offer CSCI patients access to upper-limb services that can perform tendon or nerve transfer procedures
4. Upper-limb surgeons with an interest in nerve transfer should seek specialist training in CSCI to supplement the current hand surgery curriculum
5. All upper-limb surgery following CSCI should be undertaken within the confines of a spinal injury. Patients should be counseled carefully, honestly, and with equipoise.

## Ethical consideration

Ethical approval not sought.

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## Conflicts of interest

There are no conflicts of interest.

## Authors' contributions

DMP and JAW conceived the study. JAW drafted the questionnaire and collected and analyzed the data generated. JAW wrote and revised the manuscript in conjunction with DMP. DMP and JAW both agreed the final manuscript. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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