**Hong Kong Journal of Orthopaedic Research**
*(An Open Access Journal for Orthopedics and Trauma Research)*

***Research Article***

Hong Kong J Orthop Res
ISSN (e): 2663-8231
ISSN (p): 2663-8223
2020; 3(2): 41-45
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# Pain Mapping and Neuropathic Features of Common Shoulder Pathologies

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## Abstract

**Introduction:** Pain maps can help quantify the distribution of pain but are not commonly used in shoulder pathology. This prospective study aims to quantify severity, type and distribution of pain associated with common shoulder pathologies using patient derived pain maps. **Material and Methods:** 219 patients with 5 common shoulder pathologies were prospectively recruited with diagnosis confirmed definitively at time of procedure. Patients completed maps for nociceptive pain and abnormal sensation. Visual Analogue Score and a validated neuropathic pain questionnaire (painDetect) were completed. Maps were generated with images stacked and overlaid using an FFT based image algorithm to generate pathology specific heat maps. **Results:** Neuropathic pain was likely in 20% of all patients based on painDetect scores. Abnormal sensation was present overall in 49.3%. 16.1% experienced symptoms below the elbow and 11.6% in the hand. Frozen shoulder appears to have the highest frequency of distal limb symptoms. **Conclusion:** This study provides a clear guide to the distribution and nature of pain arising from procedure confirmed common shoulder conditions. We have demonstrated that neuropathic pain is prevalent in common shoulder pathologies and may spread as far as the hand. Therefore, pain in this distribution should not be dismissed as cervical as this will lead to a delay in the treatment of the shoulder pathology.

**Keywords:** Shoulder, Pain, Neuropathic, Map, Orthopaedic surgery, painDETECT.

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## INTRODUCTION

Shoulder pathology represents a significant burden to the health service in the United Kingdom, with 1% of adults consulting their general practitioner each year with a new shoulder pain [1]. Understanding the distribution and nature of pain described by patients is fundamental to accurate clinical diagnosis and treatment. The presence of pain distal to the elbow and having neuropathic features such as burning, tingling or numbness can lead to the incorrect conclusion that the pain is not shoulder driven. It is therefore essential that the clinician has a clear comprehension of the locations and types of pain experienced by patients with common shoulder pathologies [2]. If correctly recognised, a patient with neuropathic pain may require a modified management strategy compared to patients with purely nociceptive pain [3,4]. PainDetect is a 38 point validated pain questionnaire assessing the intensity, radiation and pattern of pain to help diagnose neuropathic pain [5]. It is now frequently used to confirm this diagnosis [4,6,7].

Pain mapping has been utilised in patients with musculoskeletal pathology affecting other joints but its use in shoulder pathology has been limited [2,8,9]. Despite the frequency of shoulder pathology and pain, there have been limited studies into the distribution and type of pain experienced and where work has been undertaken into this area it has previously been limited to very few shoulder pathologies [2]. Further knowledge on the distribution of pain would be of utility to clinicians in the diagnosis and post-operative assessment of patients and is likely to facilitate patient-clinician communication.

### Aim

The aim of this study is to quantify the distribution and severity of pain abnormal sensations in common shoulder pathologies using patient derived mapping diagrams and to investigate the presence of neuropathic features using a validated neuropathic pain scoring system.

## MATERIALS AND METHODS

Consecutive patients attending a new patient shoulder clinic were prospectively recruited over a one year period for involvement in this study. They were fully assessed both clinically and radiologically within a specialist shoulder team. Patients were considered for the study following the diagnosis of a common shoulder pathology. These were frozen shoulder, osteoarthritis, irreparable cuff tear, repairable cuff tear and subacromial impingement with an intact rotator cuff.

Only data from patients listed for surgery or hydro-dilatation were included in the study with the expectation that the presumptive preoperative diagnosis would then be confirmed at surgery or hydro-dilatation. Patients were excluded if they had the following; previous surgery, diagnosis or clinical suspicion of peripheral/cervical nerve symptoms, additional diagnosis at the time of surgery and instability.

Patients with a presumptive diagnosis of shoulder instability were excluded from the study, because traumatic instability has been associated with obvious neurological injury in 13.5% of dislocations and electromyography studies show nerve injury in 48% [10,11]. Such nerve involvement would potentially result in neuropathic pain, but as a direct nerve injury.

Patients were provided with a series of assessments at the time of their outpatient visit and pre-operatively on the day of surgery. These comprised of pain mapping diagrams to assess both pain and abnormal sensation, painDETECT questionnaire, visual analogue score sheet.

### Pain Diagrams

These consisted of four diagrams of a standardised hemi-torso and upper limb on A4 paper. Patients were asked to shade their distribution of nociceptive or 'typical' pain on two of the diagrams. One diagram for the anterior, and one diagram for the posterior aspect of the shoulder. This allowed them to freely indicate the distribution of pain from the neck and chest down to the fingers. Patients were also asked to indicate the epicentre or 'point of worst pain' by drawing an 'X' on the same hemi-torso.

The remaining two diagrams were used to assess abnormal sensation. Patients were asked to shade the total area that they experienced any burning, tingling or prickling, pain from light touch, electric shocks, temperature hypersensitivity, numbness or pain on slight pressure. They were again instructed to mark the epicentre of this type of abnormal sensation with an X. Abnormal sensation was defined by these seven modalities as they are key features of neuropathic pain. Although none in isolation are diagnostic of neuropathic pain, but collectively are part of the painDETECT questionnaire.

### The painDETECT questionnaire

The painDETECT questionnaire is a validated method for assessing neuropathic pain, providing a score (0-38) indicating the likelihood of neuropathic pain being present [7]. This is a composite score using the intensity, radiation and pattern of pain as well as the presence of abnormal sensation. A score greater than 18 indicates that a neuropathic component of pain is very likely. A score of less than 13 is indicative of nociceptive pain with no neuropathic component. A score of 13-18 is considered "unclear". The diagnosis of neuropathic pain is heavily weighted towards abnormal sensation as the main diagnostic criteria. Abnormal sensory symptoms contribute to 35 out of the available maximum 38 points.

### Generating pain maps

To allow for standardisation the patient diagrams were transferred using a grid system to allow digitalisation. Each grid square was 2 x 2 mm and all squares that were greater than 50% shaded were turned to black on the image. For the worst pain (that which was marked by the cross), the same grid system was used. The individual patient maps were grouped together based on the preoperative diagnosis with anterior and posterior maps collated into one image. The maps were digitized and underwent computer summation to produce a diagram showing the distribution of "typical" pain for each shoulder pathology.

Following the collection of data pain heat-maps were generated for the presence and location of neuropathic features for each pathology group. Image analysis was done using Image J (National Institutes of Health, US). The images were stacked and overlaid using the Z stack plug-in. The maps were generated using a Python based image processing pipeline (Python Software Foundation – Wilmington, Delaware). The patient diagrams for each group were aligned using a Fast Fourier Transform based image registration algorithm with subpixel accuracy from the Scikit-Image library (Berkeley, Ca). Aligned images were then averaged to produce a group-wide pain heatmap, encoded using the gist_earth colormap (San Francisco, Ca). Statistical Analysis was undertaken using Quickcalcs (Graphpad, LaJolla, Ca).

## RESULTS

A total of 219 patients with an average age of 60 were recruited to the study. The basic demographics for each shoulder pathology group are demonstrated in Table 1. VAS scores for any pain (both nociceptive and neuropathic) are demonstrated in chart 1. There was no statistical significant difference between the groups. The epicentre of pain for all pathologies was in the shoulder region as demonstrated in pain map 1. Chart 2 and pain map 2 demonstrate the distribution of nociceptive pain. With all pathologies grouped together 13% of patients reported pain below the elbow and 8% reported pain in the hand. Chart 3 and pain map 3 demonstrate distribution of abnormal sensation. When the different diagnosis groups are combined, nearly half of patients (49.3%) experience abnormal sensations above the elbow and over a quarter (27.7%) experience abnormal sensations below the elbow (Chart 4). Percentages of patients with an unclear (13-18) or likely (>18) PainDETECT score are shown in Chart 5.

Where frozen shoulder was treated with hydro-dilatation, there was no statistical difference in the age, VAS, painDETECT score, incidence or patterns of pain when compared to patients treated with arthroscopic capsular release.

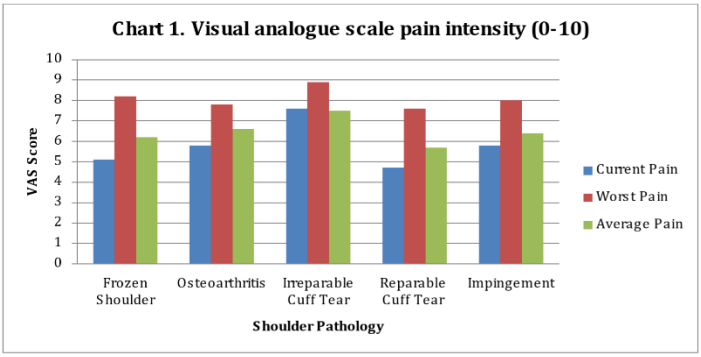



**Chart 1:** Visual analogue scale intensity (0-10)

**Table 1:** Average age by Shoulder Pathology

| | Frozen Shoulder | Osteoarthritis | Irreparable Cuff Tear | Repairable Cuff Tear | Impingement (intact cuff) |
|---|---|---|---|---|---|
| Number of patients | 48 | 37 | 15 | 87 | 32 |
| Mean Age (SD) | 53 (+/- 9.3) | 74 (+/- 8.3) | 77.2 (+/- 6.4) | 58.1 (+/- 9.2) | 53.1 (+/- 10.5) |

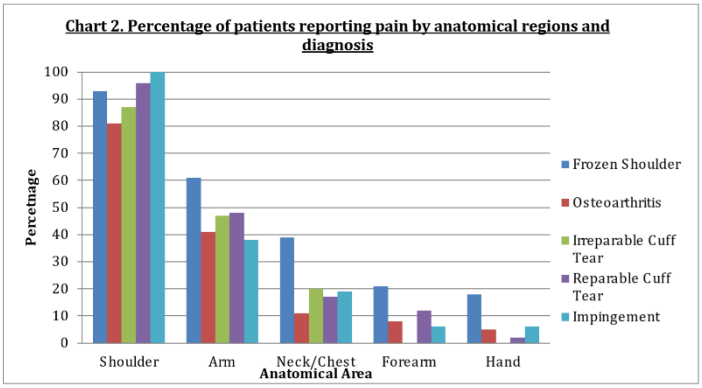



**Chart 2:** Percentage of patients reporting pain by anatomical location and diagnosis

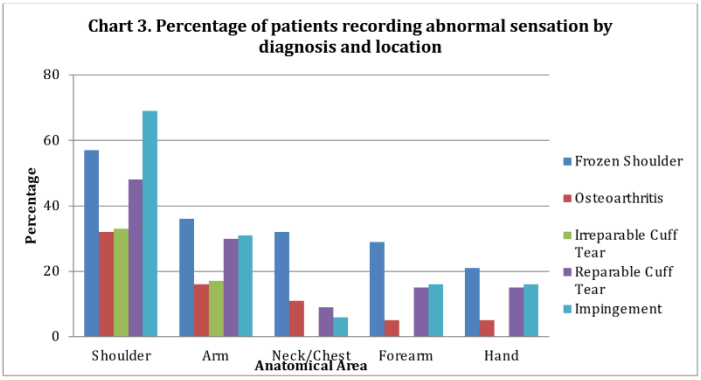



**Chart 3:** Percentage of patients recording abnormal sensation by diagnosis and location

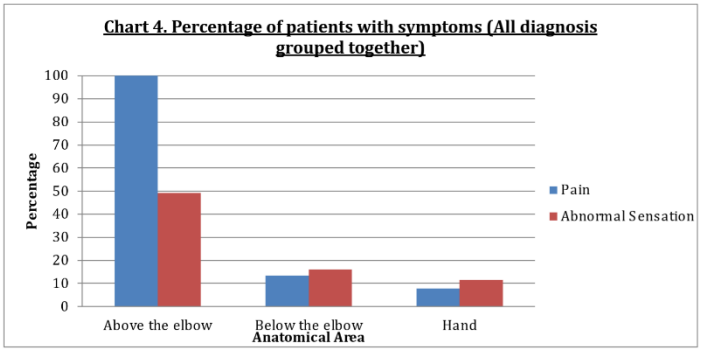



**Chart 4:** Percentage of patients with symptoms (all diagnoses grouped together)

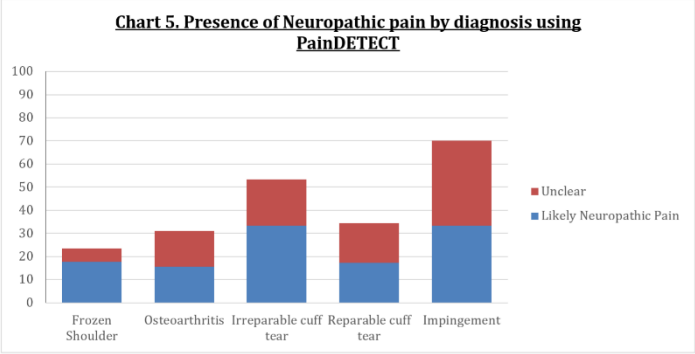
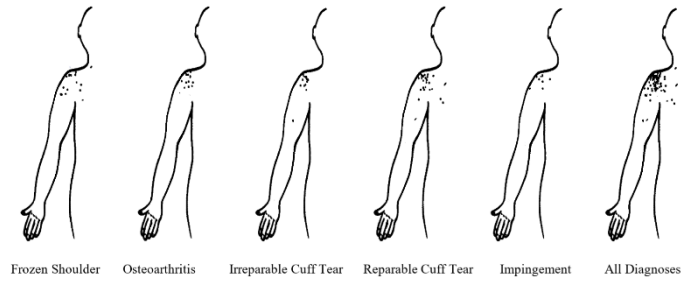
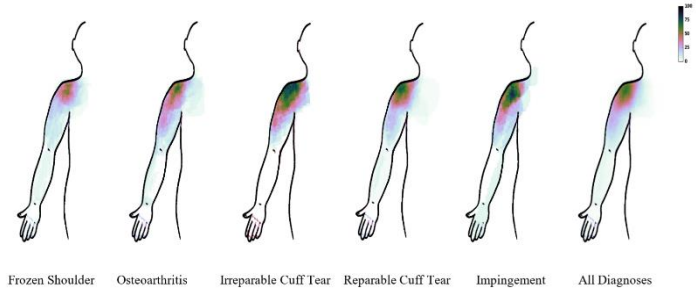


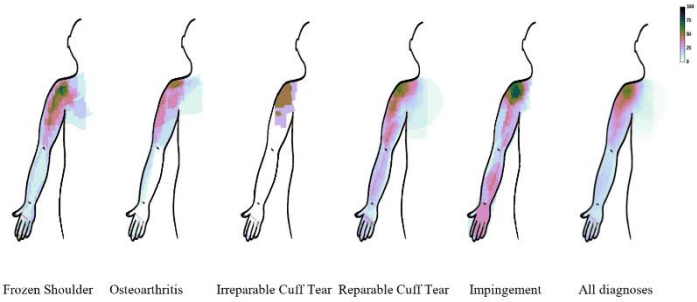

**Chart 5:** Percentage of neuropathic pain by diagnosis using PainDETECT




**Pain map 1:** Epicentre of pain




**Pain map 2:** Distribution of nociceptive pain




**Pain map 3:** Distribution of abnormal sensation

## DISCUSSION

This is the largest prospective study to map neuropathic pain around the shoulder in common shoulder conditions. As would be expected, the epicentre of pain in all conditions studied is focussed on the shoulder. But we have also demonstrated a considerable proportion of patients with pain and altered sensation distal to the elbow. Bayam et. al. also reported on pain mapping in the shoulder [2], however, the use of novel software techniques in this study allows the creation of heat maps which visually represent the spread and gradient of these symptoms for each pathology. The maps in this study were generated by the patients themselves and therefore the patient had complete choice over the exact distribution of the pain, rather than limited to 14 areas on the front and back of the arm [2]. We also used surgical confirmation of diagnosis for inclusion in the study rather than clinical and radiological dependence, helping eliminate concerns about the low specificity of often-used shoulder special tests or imaging [12].

Nociceptive pain is the typical pain associated with tissue damage and the resulting inflammatory pathways [4]. It is adaptive, in that it elicits physiological responses that initiate healing [13]. Neuropathic pain is defined by the International Association for the Study of Pain (IASP), as pain initiated or caused by a primary lesion or dysfunction in the peripheral or central nervous system [14,15]. It is not necessary to have a clearly defined or demonstrated lesion within the nervous system to have neuropathic pain. Neuropathic pain is more likely to occur in the presence of chronic nociceptive pain. It is associated with the more severe end of the pain spectrum [7,17,18,19]. It is felt to be a

manifestation of central sensitisation and has previously been shown to predict a poorer outcome with surgical treatment of impingement, however, other studies have shown that neuropathic pain can be successfully treated with surgical intervention and may relate to removing the primary nociceptive drive [20].

Understanding these two distinct pain systems and how their presentations may alter both in distribution and pain qualities can greatly aid with diagnosis and help the treating clinician target treatment specific to the pathology and type of pain the patient is experiencing.

In this study, the point of worst pain experienced in all of the shoulder pathologies was almost completely focused on the deltoid region. Distal nociceptive pain decreased in a stepwise manner with increasing distance from the shoulder region. Patients with frozen shoulder were the most likely to have nociceptive pain radiating distal to the elbow and a third of these patients also demonstrated pain radiating more proximally to the shoulder.

Far from being an uncommon sequelae of shoulder pathology, results from the painDETECT questionnaire record an incidence of likely neuropathic pain in at least 15% of patients presenting with the five pathologies studied. Only a third of patients with impingement were unlikely to have any neuropathic element to their pain. However, the distribution of this neuropathic pain appeared very variable between the pathologies. Whilst much lower percentages of patients treated for frozen shoulder and repairable cuff tears scored as being likely to have neuropathic pain on their painDETECT scores, these groups of patients were more likely to see spread of abnormal sensation into the hand and distal to the elbow than those with irreparable cuff tears or osteoarthritis.

Patients with neuropathic pain have a higher incidence of depression and anxiety [4]. These patients may require alternative analgesia that specifically targets neuropathic pain [3,4]. These patients may not respond as well to surgical intervention and may take longer to recover from surgery [7,22].

This study would have benefited from postoperative pain mapping assessment of this cohort of patients as this would have added to the story of how neuropathic pain is experienced in these shoulder conditions. Although the neck was clinically assessed as standard as part of the work up for these conditions, formal imaging of the neck would have added weight to these findings and aided further in distinguishing pain arising from the shoulder pathology and that arising from more proximal. It remains, however, one of the largest studies of pain mapping in shoulder surgery and these findings should aid clinicians in decision making around shoulder pathology.

**CONCLUSION**

This study provides a clear guide to the distribution and nature of pain arising from surgically confirmed common shoulder pathologies. We have demonstrated that the presence of neuropathic pain is common in all the shoulder pathologies studied, particularly in impingement syndrome. These symptoms may potentially spread as far as the hand.

All patients presenting to the shoulder clinic should be screened for cervical pathology, but based on these results, altered sensation and symptoms distal to the elbow should not be dismissed as purely spinal in origin. This may even result in a delay in the diagnosis of shoulder pathology. If neuropathic symptoms are present, pre-operative counselling can be focussed on the consideration of alternative pain medication and patient expectation.

**Conflicts of interest**

The authors declare no conflicts of interest.

**Source of funding**

None.

**Informed consent**

Written informed consent was obtained from all patients for their anonymised information to be published in this article.

**Ethical Approval**

Ethical approval for this study was waived by Royal Devon & Exeter Hospital Review board because patient care was not impacted by participation in the study. This study was completed in accordance with the Helsinki Declaration as revised in 2013.

**Contributorship**

SD was involved in data collection and analysis, literature research and drafting of the paper. AK, and TB were involved in data analysis, literature research and drafting the paper. JE and JM were involved in data collection and analysis. SG was involved in patient recruitment and data collection and analysis. KD, CS and JK conceived the idea, recruited patients, collected data and were involved in drafting the paper. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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