Neuropathic Pain after Shoulder Arthroplasty: Prevalence, Impact on Physical and Mental Function, and Demographic Determinants

Helen Razmjou, PT, PhD;^{*†‡} Linda J. Woodhouse, PT, PhD;^{§¶}
Richard Holtby, BS, MB, FRCSC^{**††}

ABSTRACT

Purpose: The objectives of this survey study were to provide an estimate of the prevalence of neuropathic pain (NP) and to explore the cross-sectional and longitudinal group differences postoperatively. **Method:** A cohort of consecutive patients who had undergone total shoulder arthroplasty (TSA), reverse shoulder arthroplasty (RSA), or humeral head replacement (HHR) were surveyed within an average of 3.8 years after surgery. Questionnaires completed at the time of the survey were the Self-Administered Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS) pain scale, the visual analogue scale (VAS) for pain, the Western Ontario Osteoarthritis of the Shoulder (WOOS) index, the Patient Health Questionnaire-9 (PHQ-9), and a satisfaction questionnaire. **Results:** Of the 141 candidates who were invited to participate in the study, 115 patients participated (85 TSA, 21 HHR, and 9 RSA), for an 82% response rate. Five patients (4%) met the criteria for NP, of whom one had a loosening of the prosthesis and required further surgery. Having NP was associated with greater pain (VAS; $p = 0.001$), greater depression (PHQ-9; $p = 0.001$), more disability (WOOS; $p = 0.030$), and less satisfaction with the surgery ($p = 0.014$). There was no relationship between the presence of NP and patients' age, sex, preoperative pain, range of motion results, or WOOS scores ($p > 0.05$). **Conclusions:** Persistent pain of neuropathic origin is not common after shoulder arthroplasty, but it is a significant contributor to poor mental and physical well-being and thus warrants further research.

Key Words: neuropathic pain; prevalence; shoulder arthroplasty.

RÉSUMÉ

Objectif: la présente étude par sondage visait à évaluer la prévalence de la douleur neuropathique (DN) et à explorer les différences transversales et longitudinales des groupes après l'opération. **Méthodologie:** la présente étude visait à sonder une cohorte de patients consécutifs qui avaient subi une arthroplastie totale de l'épaule (ATÉ), une arthroplastie inversée de l'épaule (AIÉ) ou un remplacement de la tête de l'humérus (RTH), en moyenne 3,8 ans après l'intervention. Au moment du sondage, les patients ont rempli les questionnaires sur l'échelle autoadministrée de la *Leeds Assessment of Neuropathic Symptoms and Signs* (S-LANSS; évaluation des signes et symptômes de la douleur neuropathique de Leeds), l'échelle visuelle analogique (ÉVA) de la douleur, le score du *Western Ontario Osteoarthritis of the Shoulder* (arthrose de l'épaule de Western Ontario, ou WOOS), le questionnaire sur la santé du patient-9 (PHQ-9) et un questionnaire sur la satisfaction. **Résultats:** des 141 candidats qui ont été invités à participer à l'étude, 115 ont obtenu le questionnaire (85 ATÉ, 21 RTH et 9 AIÉ), ce qui représente un taux de réponse de 82 %. Cinq patients (4 %) respectaient les critères de DN, dont un présentait un descellement de la prothèse qui nécessitait une nouvelle opération. La DN s'associait à plus de douleur (ÉVA, $p = 0,001$), plus de dépression (PHQ-9, $p = 0,001$), plus d'incapacité (WOOS, $p = 0,030$) et moins de satisfaction envers l'opération ($p = 0,014$). Il n'y avait pas de relation entre la DN du patient et son âge, son sexe, sa douleur préopératoire, son amplitude de mouvements après l'opération ou les scores WOOS ($p > 0,05$). **Conclusions:** la douleur persistante d'origine neuropathique n'est pas courante après une arthroplastie de l'épaule, mais elle nuit de manière significative au bien-être mental et physique, ce qui justifie la poursuite des recherches sur le sujet.

Shoulder arthroplasty is an effective means of improving pain and disability in patients with advanced osteoarthritis of the glenohumeral joint.¹⁻⁷ However, a subset

of patients continues to suffer from persistent postoperative pain.⁸⁻¹⁰ The postoperative pain is either nociceptive or neuropathic in nature. *Nociceptive* is taken from the

From the: *Department of Rehabilitation, Holland Orthopaedic & Arthritic Centre; ‡Sunnybrook Research Institute; **Division of Orthopaedic Surgery, Department of Surgery, Sunnybrook Health Sciences Centre; †Department of Physical Therapy; ††Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto, Toronto; §Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton; ¶McCaig Institute for Bone and Joint Health, Calgary.

Correspondence to: Helen Razmjou, Holland Orthopaedic & Arthritic Centre, 43 Wellesley St. E., Toronto, ON M1Y 1H1; helen.razmjou@sunnybrook.ca.

Contributors: All authors designed the study; or collected, analyzed, or interpreted the data; and drafted or critically revised the article and approved the final draft.

Competing Interests: Helen Razmjou was partially supported by the Holland Centre Musculoskeletal Clinician Investigator Funding Program and the Suzanne and William Holland Funding, Sunnybrook Health Sciences Centre, during the study period.

Physiotherapy Canada 2018; 70(3);212-220; doi:10.3138/ptc.2016-99

Latin word *nocere* and means “harm” or “hurt,” referring to noxious chemical, thermal, and mechanical stimuli mediated by the receptors in the skin, bone, connective tissue, and muscles. In contrast, *neuropathic pain* (NP) is elicited from an injury or disease of the neurons in the peripheral or central nervous system.^{11–13} Whereas nociceptive pain is caused by the stimulation of pain receptors and resolves once the stimulus has been removed, NP is produced by the release of inflammatory mediators, including neuropeptides and neurotransmitters, secondary to injury or damage to peripheral nerves or the central nervous system,^{14,15} and it may persist for months or years beyond the apparent healing of the damaged tissues. Nociceptive pain tends to be well localized, sharp, aching, or throbbing in nature. NP is described as burning, tingling, or shooting or like electric shock in nature, and it is particularly recognized by the presence of chronic allodynia (pain resulting from a light stimulus) and hyperalgesia (increased sensitivity to normal stimuli).^{16–19}

There is a significant literature on NP occurring after lower extremity joint replacement.^{20–27} However, there is minimal information on NP after shoulder arthroplasty. The only study, by Bjørnholdt and colleagues,¹⁰ reported the prevalence of presumed NP to be 13% at 1 or 2 years post-shoulder arthroplasty. In their study, Bjørnholdt and colleagues translated a French questionnaire, the Douleur Neuropathique (DN4),²⁸ into Danish to measure NP in their sample, whose data they had extracted from the Danish Shoulder Arthroplasty Register. The DN4 has not been validated for sensitivity or specificity in patients with shoulder arthroplasty, and further assessment of the subject in a different population with a more established measure of NP will add to the body of knowledge in this area.

Persistent pain of neuropathic origin is a significant contributor to poor physical function, impaired health-related quality of life, and greater use of health care.^{29,30} Exploring the prevalence of this disabling condition, which results in intractable pain after shoulder arthroplasty and its potential predisposing factors, warrants further research. The objectives of this study were to provide an estimate of the prevalence of NP and to explore the cross-sectional and longitudinal differences between patients with and without postoperative NP. In addition, the role of patient characteristics in the presence of postoperative NP was explored.

METHODS

Patient population

This was a survey of a cohort of consecutive patients who had undergone total shoulder arthroplasty (TSA), humeral head replacement (HHR), or reverse shoulder arthroplasty (RSA) over a period of 12 years (2002–2014). The inclusion criteria were individuals aged older than 18 years and a diagnosis of advanced osteoarthritis of

the glenohumeral joint with or without rotator cuff tear requiring a shoulder replacement. The exclusion criteria included the inability to speak or read English, evidence of infection, underlying metabolic disease, osteonecrosis, or capsulorraphy arthropathy. Patients with primary osteoarthritis and an intact rotator cuff underwent TSA, and patients with rotator cuff tear arthropathy or massive rotator cuff tear underwent RSA. HHR was performed in younger patients with a normal glenoid articular surface or those with severe glenoid deficiency. Standardized preoperative clinical data, surgical findings, and follow-up data that had been collected prospectively were extracted from a shoulder research database. All subjects provided informed consent. Approval for use of human subjects was obtained from the Research Ethics Board of the Sunnybrook Health Sciences Centre.

Rehabilitation

All patients were given a comprehensive rehabilitation protocol to follow after surgery. A sling was worn for 2 weeks after TSR or HHR and for 4 weeks after RSA; active assisted mobilization started on day 1 after surgery. Sub-maximal isometric exercises started at 4 weeks after TSR or HHR and 6 weeks after RSA. Active exercises started at 6 weeks in a lying position and progressing to an upright position. Resistive exercises started at 8–10 weeks after TSR or HHR and 12 weeks after RSA. Exercises related to internal rotation followed the other directions of movement with a 4-week delay to avoid strain on the subscapularis tendon.

Baseline and follow-up outcome measures

Baseline data were collected at 2–3 weeks before surgery, and follow-up data were collected at 6 months and 1 year after surgery. Baseline and follow-up data included the visual analogue scale (VAS) for average pain, the Western Ontario Osteoarthritis Shoulder (WOOS) index for self-reported disability,⁵ and active, pain-free range of motion (ROM). The ROM assessment was performed with the patient in an upright position and was based on the performance component of the Constant-Murley score.³¹ Flexion, abduction, external rotation, and internal rotation (hand behind back) were measured separately and given a score ranging from 0 to 10 for each direction (maximum 40).

Survey outcome measures

The questionnaires completed at the time of the survey were (1) the Self-Administered Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS) pain scale,³² which was used to identify the existence of NP after surgery; (2) the WOOS index, to measure self-reported disability;⁵ and (3) the Patient Health Questionnaire–9 (PHQ–9), to identify potential depressive or mental disorders.³³ In addition, all patients were asked to rate the amount of pain on an average day using the VAS and to respond to the following question: “How satisfied are

Figure 1 Diagram of recruitment process.

TSA = total shoulder arthroplasty; HHR = humeral head replacement; RSA = reverse shoulder arthroplasty.

you with the results of your surgery?" Their satisfaction level was rated on a 6-point Likert scale: *very satisfied*, *somewhat satisfied*, *a little bit satisfied*, *a little bit dissatisfied*, *somewhat dissatisfied*, and *very dissatisfied*.

S-LANSS scores range from 0 to 24,^{34,35} and scores of 12 or more suggest NP;^{35,36} the S-LANSS has shown validity and reliability for identifying NP after lower extremity joint arthroplasty.^{26,27,32} The WOOS index has 19 questions and has been reported to be valid and reliable in patients with glenohumeral osteoarthritis.⁵ The PHQ-9 has nine items and has shown validity in patients with musculoskeletal disorders and osteoarthritis.^{37–41}

Initially, a letter that described the nature of the study was mailed to study candidates. A second letter with five questionnaires attached was mailed approximately 10 days later. Patients who did not respond received another reminder at approximately 2 months. The 6-week and 3-month post-surgical data and the most recent medical records of patients who met the criteria for having NP were reviewed to rule out any prosthetic failure or other medical conditions that might have contributed to chronic NP.

Sample size

The sample size calculation for estimating the prevalence was based on a formula suggested by Daniel.⁴² In this formula,

$$n = \frac{Z^2 P(1 - P)}{d^2}$$

Z is the Z statistic for level of confidence (1.96 for 95% CI), P is the expected prevalence of 13%, and d is precision. Use of a precision of 10% or more has been suggested for preliminary studies that are investigating the

prevalence of an unknown condition. For the purpose of this study, with a level of confidence of 1.96 and a better precision of 7%, a minimum of 89 cases with complete data were deemed necessary.

Statistical analysis

The estimate of prevalence was calculated as number of NP cases divided by the total number of subjects. Descriptive statistics (means, SD) were calculated for variables of interest for NP and non-NP groups.

Cross-sectional group differences

Baseline and follow-up differences between the NP and non-NP groups in pain, perceived disability, and level of depressive or mental conditions were explored using the VAS, WOOS, and PHQ-9, respectively. Cross-sectional differences were examined using Wilcoxon two-sample tests for non-normally distributed continuous data. Recovery from pain and disability was examined as the amount of change in VAS and WOOS between baseline data and data collected at the time of the survey. Fisher's exact tests were used for categorical data.

Predictors of neuropathic pain

The S-LANSS score was the dependent variable. The predictors of NP were age, sex, and baseline, 6-month, and 1-year VAS, ROM, and WOOS scores. Univariable logistic regressions were used to examine the relationship between NP and individual predictors. Statistical analyses were performed using the SAS statistical software (version 9.1.3; SAS Institute, Cary, NC). Statistical results were reported using two-tailed p -values, with significance set at $p < 0.05$.

RESULTS

A total of 141 patients were contacted, of whom 115–67 (58%) women and 48 (42%) men, for a response rate of 82%—participated in the study (see Figure 1). Five patients had bilateral surgeries. To avoid bias related to using patients with bilateral problems as independent cases due to violating the assumption of independence,^{43–46} one joint of the patients who had bilateral surgeries was randomly selected and included in the study. We found no statistically significant differences in age, sex, or preoperative level of disability on the basis of respondents' and non-respondents' WOOS ($p > 0.05$). The final sample included 85 (74%) participants with TSA, 21 (18%) participants with HHR, and 9 (8%) participants with RSA. The mean time frame between surgery and final data collection was 3.8 (SD 2) years, with a range of 2–12 years.

Estimated prevalence

Five patients with TSA met the criteria for having NP (NP group; prevalence 4%). The means on the S-LANSS were 18.20 (SD 2.4) and 0.52 (SD 1.70) for the NP and non-NP groups, respectively.

None of the patients with NP had bilateral shoulder joint arthroplasty. All patients had osteoarthritis of the

Table 1 Baseline Differences in Patients with and without NP

Variable	No. (%) of patients*		Statistics	
	NP group (<i>n</i> = 5)	Non-NP group (<i>n</i> = 110)	Z-value,** FET, or <i>t</i> -value	<i>p</i> -value
Age, y, mean (SD)	65 (10)	69 (9)	1.22	0.22
Sex			FET = 0.24	0.40
Female	2 (40)	66 (60)		
Male	3 (60)	44 (40)		
Affected side			FET = 0.22	0.38
Right	4 (80)	50 (45.4)		
Left	1 (20)	60 (54.5)		
Type of arthroplasty			FET = 0.21	0.72
TSA	5 (100)	80 (72.7)		
HHR	—	21 (19.1)		
RSA	—	9 (8.2)		
Mechanism of injury			FET = 0.24	0.32
Insidious	3 (60)	86 (78.2)		
Traumatic	2 (40)	24 (21.8)		
Symptom duration, mo, mean (SD)	10.08 (9)	7.42 (7)	<i>t</i> = 0.66	0.54
Self-report outcome measures, mean (SD)				
Baseline				
WOOS (0–100)	23.00 (11)	28.50 (17)	0.47	0.64
VAS (0–10)	5.00 (3)	6.35 (3)	1.09	0.27
6 mo				
WOOS (0–100)	67.33 (33)	75.15 (22)	0.34	0.73
VAS (0–10)	1.33 (2)	1.78 (2)	0.25	0.80
1 y				
WOOS (0–100)	69.20 (26)	79.44 (21)	0.93	0.35
VAS (0–10)	1.80 (2)	1.40 (2)	0.05	0.96
Range of motion (0–40°)				
Baseline	8.00 (6)	8.24 (6)	0.01	0.99
6 mo	21.33 (16)	23.38 (9)	0.00	1.00
1 y	22.80 (15)	26.24 (9)	0.33	0.74

*Unless otherwise indicated.

† Z-values are based on the Wilcoxon two-sample non-parametric test.

NP = neuropathic pain; FET = Fisher's exact test; TSA = total shoulder arthroplasty; HHR = humeral head replacement; RSA = reverse shoulder arthroplasty; WOOS = Western Ontario Osteoarthritis of the Shoulder index; VAS = visual analogue scale.

glenohumeral joint, with non-specific synovitis intraoperatively. There was no history of alcoholism or diabetes among the patients with NP. No patient had a documented history of cervical radiculopathy or carpal tunnel syndrome before or after surgery. One patient had a history of chronic pain. Review of the 6-week and 3-month postoperative data did not indicate any evidence of intraoperative or perioperative nerve injury.

The mean amount of time between date of surgery and the last clinical or imaging assessment was 1.95 (SD 0.5) years. An electronic data search and the most recent radiographs and follow-up reports of the patients with NP showed a loosening of the prosthesis in only one case at 5 years after surgery. This patient had an associated rotator cuff tear for which he had a repair before undergoing TSA.

Cross-sectional group differences

No statistically significant group differences were found in age, sex distribution, mechanism of injury, or symptom duration. The VAS and WOOS scores and ROM

results were comparable between the groups at baseline and at 6 months and 1 year after surgery (see Table 1). However, cross-sectional comparisons at the time of the survey revealed statistically significant group differences on the VAS, WOOS, and PHQ-9, with the NP group having more pain, disability, and depression (see Table 2). The lack of group differences at baseline may indicate the absence of NP before surgery because this condition is associated with higher reports of pain and physical and mental disability.

Of the non-NP group, 107 (97%) patients reported being satisfied with the surgery, and only 3 patients reported being dissatisfied. Although 2 participants (40%) in the NP group reported dissatisfaction, having NP did not affect overall satisfaction in 3 (60%) patients in that group (see Table 2).

Recovery

The change over time in VAS and WOOS was assessed between the baseline and postoperative scores collected at the time of the survey. The NP group did not report any

Table 2 Cross-Sectional Group Differences at Time of Survey in VAS, WOOS, PHQ-9, and Satisfaction

Variable (interval)	Mean (SD)		Statistics*	
	NP group (n = 5)	Non-NP group (n = 110)	Z-value or FET	p-value
VAS (0–10)	7 (1)	1 (2)	3.94	0.001
WOOS (0–100)	60 (37)	88 (16)	–2.19	0.030
PHQ-9 (0–27)	7 (4)	2 (4)	3.46	0.001
Satisfaction, no. (%)†			0.014	0.014
Very satisfied	3 (60)	92 (83.6)		
Somewhat satisfied	0	13 (11.8)		
A bit satisfied	0	2 (1.8)		
A bit unsatisfied	0	1 (0.9)		
Somewhat unsatisfied	1 (20)	1 (0.9)		
Very dissatisfied	1 (20)	1 (0.9)		

*Based on the Wilcoxon two-sample test.

†Statistics were calculated for two categories: *satisfied* and *unsatisfied*.

NP = neuropathic pain; FET = Fisher's exact test; VAS = visual analogue scale; WOOS = Western Ontario Osteoarthritis of the Shoulder index;

PHQ-9 = Patient Health Questionnaire–9.

improvement in pain ($p = 0.33$) or disability ($p = 0.08$) over time, and the non-NP group showed a statistically significant improvement in both scores ($p < 0.0001$).

Predictors of neuropathic pain

We found no relationship between age, sex, and baseline VAS, WOOS, or ROM scores on the one hand and development of NP ($p > 0.05$) on the other (see Table 3). Similarly, neither the 6- nor the 12-month VAS, WOOS, or ROM scores predicted NP at an average of 3.8 years after surgery ($p > 0.05$).

DISCUSSION

To reduce selection bias associated with the prevalence of NP, our study population consisted of patients with advanced osteoarthritis of the glenohumeral joint who had undergone three different arthroplasty procedures. We contacted all patients who met the inclusion criteria and had an acceptable response rate of 82%. The present study showed that five patients (4%) had experienced persistent pain of neuropathic origin at an average of 3.8 years after TSA, and none of them had

neurological damage according to 6-week or 3-month data. One patient experienced a mechanical failure of the prosthesis and underwent a revision surgery 5 years after the original TSA and 1 year after completing the survey. Of interest is the fact that none of the patients in our sample who had RSA or HHR reported NP despite a much higher incidence of neurological deficits reported in non-anatomic arthroplasties.⁴⁷

There has been an increasing interest in postoperative NP in the field of arthroplasty.^{20–27} In the early stages of healing after joint arthroplasty, surgically related inflammation or damage to tissues is expected to produce nociceptive pain. However, why a subset of patients continues to have persistent pain long after the local inflammation or hyperthermia has subsided is not clear. Failure after shoulder arthroplasty has been attributed to rotator cuff insufficiency,⁴⁸ excessive posterior glenoid wear,^{9,49} periprosthetic fractures, aseptic loosening of the glenoid component, or pain secondary to perioperative neurological complications.⁸ Common nerve injuries after shoulder arthroplasty involve brachial plexus or axillary nerve damage,⁵⁰ with occasional radial nerve⁵¹ or median nerve palsy.⁵² Factors that contribute to peripheral nerve injuries involve manipulation of the arm,⁵³ aberrant retractor placement, excessive traction,⁵⁴ interscalene blockade,⁵⁵ and the actual design of the implant, which may increase strain on the lateral and medial roots of the median nerve.⁵² Fortunately, arthroplasty-related neurological injuries are relatively rare, and the majority are reversible within a few months.^{47,56,57}

The NP prevalence of 4% in our study is lower than that reported by Bjørnholdt and colleagues,¹⁰ who stated a prevalence of 13% in 538 patients at 1 or 2 years after shoulder arthroplasty. Bjørnholdt and colleagues used a Danish version of the DN4 to measure NP. The DN4 consists of 10 items: 7 items are related to the quality of pain and its association with abnormal sensations and are based on an interview with a patient, and 3 items are related to a clinical examination and include the presence or absence of touch or pinprick hypoesthesia and tactile allodynia. The total score is calculated as the sum of all 10 items, and the cutoff value for the diagnosis of NP is a total score of 4 out of 10. In Bjørnholdt and colleagues' study, a score of 4 out of 7 was considered to be positive NP.¹⁰

Table 3 Preoperative Predictors of Neuropathic Pain Development

Independent variable	Wald χ^2	p-value	OR	95% CI
Sex, male/female	0.75	0.39	0.04	0.7, 2.77
Age, y	1.30	0.25	0.95	0.86, 1.04
Preoperative VAS for pain (0–10)	1.28	0.26	0.82	0.59, 1.15
Preoperative WOOS for disability (0–100)	0.51	0.48	0.98	0.92, 1.04
Preoperative pain-free ROM (0–40)	0.01	0.93	0.99	0.86, 1.15

OR = odds ratio (point estimate); VAS = visual analogue scale; WOOS = Western Ontario Osteoarthritis of the Shoulder index; ROM = range of motion.

The DN4 questionnaire was originally developed in French,²⁸ and although it has established validity in French for low back pain, traumatic nerve injuries, inflammatory osteoarthritis, and diabetes mellitus,^{28,58–60} it has not been validated in patients with shoulder arthroplasty or in Danish. In a validity study by Walsh and colleagues,⁶¹ there was fair agreement between the S-LANSS and the DN4 in patients with low-back-related leg pain. NP was identified in 15 subjects (33%) using the S-LANSS and in 19 subjects (42%) using the DN4, indicating that the DN4 might have exaggerated the existence of NP. We are in agreement with Walsh and colleagues⁶¹ that the cutoff point for the classification of NP of the S-LANSS and DN4 may not be congruent and that the DN4 may overestimate the presence of NP.

The prevalence of 4% after shoulder arthroplasty was lower than that reported for total knee arthroplasty (TKA), which ranges from 6%^{24,25} to 43%.⁶² Most commonly, the prevalence rate is reported at 10%–15%, with values reported of 11%,⁶³ 13%,²³ and 14%.^{26,64} In a recent study that examined the prevalence and predictive value of patient-related factors after TKA, no relationship was found among age, sex, and development of NP.²⁶ However, the NP group reported higher levels of pain, stiffness, and physical dysfunction than the non-NP group as early as 1 year after surgery. One explanation for the lower rate of NP in patients after TSA may be the lower level of morbidity and mortality in patients undergoing shoulder compared with knee arthroplasty.^{65,66} Fehringer and colleagues⁶⁶ reported that after adjusting for multiple risk factors, the number of complications and readmissions and length of stay were lower for patients with TSA than for patients with TKA. This may also account for the delay in the development of NP in shoulder patients. On the basis of our findings, the development of NP occurred at some point between 1 year and an average of 3.8 years after the surgery.

Patients identified as having NP had similar levels of pain, disability, and ROM before surgery and at 6 months and 1 year after surgery. However, at an average of 3.8 years, the pain (VAS) and physical disability (WOOS) reported by the NP group were higher at a statistically significant level. In addition, the NP group reported higher levels of depression and lower levels of overall satisfaction with the surgery. The presence of depression, anxiety, and higher disability is significantly and independently associated with persistent pain after TKA^{25,27,67,68} and is expected to be the case after upper extremity arthroplasty. In the present study, the average PHQ–9 score of 7 indicates mild depression, and the VAS score of 7 out of 10 and WOOS score of 60 out of 100 indicate moderate to severe pain and disability, respectively.

In our study, age, sex, mechanism of injury, and symptom duration were not predictors of developing NP, and neither preoperative pain nor perceived disability played a significant role in the development of NP. There

is evidence that some patients with advanced osteoarthritis undergoing joint replacement have altered pain perception before surgery.^{69–71} Production of inflammatory cytokines may promote local chronic inflammation of the joint, leading to NP in a subset of patients with osteoarthritis.^{72,73} However, a lack of significant between-group differences before surgery and at 6 months and 1 year after surgery may indicate that NP symptoms took longer than 1 year to develop. Measuring inflammatory factors in the synovial fluid of candidates for arthroplasty in future studies may improve our understanding of the predictors of NP development after joint arthroplasty surgery.

In terms of satisfaction, although the NP group was more likely to be dissatisfied with the surgery, three patients in this group reported high satisfaction. Reporting being content with surgery despite experiencing persistent pain may be related to better coping abilities and the response-shift phenomenon known to occur after musculoskeletal surgeries.^{74,75} The relationship between NP and satisfaction with surgery has been explored in patients after TKA: Phillips and colleagues⁶⁴ reported that more than 80% of the dissatisfied patients had high levels of pain, and 45% had possible NP.

Our study has several limitations. First, it used the data of patients operated on by one surgeon who specialized in shoulder arthroplasty reconstruction at an academic centre, and these data may limit the generalizability of our results and underestimate the prevalence of NP in non-academic centres. Other limitations of the study are those characteristics of survey designs. For example, the time frame between the arthroplasty and the survey was different for each patient, and the presence of NP before surgery could not be verified because the S-LANSS was not available at baseline. In addition, the present study was based on self-report tools; including an objective sensory assessment in future studies will improve the accuracy of detecting NP. Finally, the results of an analysis of rare conditions in cohort studies should be viewed with caution.

CONCLUSIONS

The prevalence of NP was 4% after shoulder arthroplasty; it was associated with higher levels of disability and depression and with lower satisfaction with the surgery at an average of 3.8 years after TSA. Patient demographics were not predictors of NP development. Although persistent pain of neuropathic origin does not appear to be common after shoulder arthroplasty, when present, it seems to contribute to poor mental and physical well-being and warrants further research.

KEY MESSAGES

What is already known on this topic

There is a significant body of knowledge on neuropathic pain (NP) after lower extremity joint replacement.

However, information on the prevalence and nature of the factors that may contribute to developing NP after shoulder arthroplasty is very limited.

What this study adds

This study showed that only 4% of patients who had undergone shoulder arthroplasty featured NP qualities that could not be explained by preoperative characteristics. Patients who participated in the present study did not differ in pain, disability, or range of motion up to 1 year after surgery; this finding may indicate a need for a more comprehensive assessment of neuropathic symptoms at longer follow-ups. Diagnostic and therapeutic strategies implemented early in the course of recovery are expected to improve satisfaction with surgery, and physical and mental well-being, in patients who may develop NP in the future.

REFERENCES

- Mansat P, Mansat M, Bellumore Y, et al. Résultats à moyen terme de la prothèse d'épaule dans l'omarthrose primitive [Mid-term results of shoulder arthroplasty for primary osteoarthritis]. *Rev Chir Orthop Reparatrice Appar Mot.* 2002;88(6):544–52. Medline:12447123.
- Norris TR, Iannotti JP. Functional outcome after shoulder arthroplasty for primary osteoarthritis: a multicenter study. *J Shoulder Elbow Surg.* 2002;11(2):130–5. <http://dx.doi.org/10.1067/mse.2002.121146>. Medline:11988723
- Razmjou H, Stratford P, Kennedy D, et al. Pattern of recovery following total shoulder arthroplasty and humeral head replacement. *BMC Musculoskelet Disord.* 2014;15(1):306. <http://dx.doi.org/10.1186/1471-2474-15-306>. Medline:25234000
- Razmjou H, Holtby R, Christakis M, et al. Impact of prosthetic design on clinical and radiologic outcomes of total shoulder arthroplasty: a prospective study. *J Shoulder Elbow Surg.* 2013;22(2):206–14. <http://dx.doi.org/10.1016/j.jse.2012.04.016>. Medline:22819578
- Lo IK, Griffin S, Kirkley A. The development of a disease-specific quality of life measurement tool for osteoarthritis of the shoulder: The Western Ontario Osteoarthritis of the Shoulder (WOOS) index. *Osteoarthritis Cartilage.* 2001;9(8):771–8. <http://dx.doi.org/10.1053/joca.2001.0474>. Medline:11795997
- Gartsman GM, Roddey TS, Hammerman SM. Shoulder arthroplasty with or without resurfacing of the glenoid in patients who have osteoarthritis. *J Bone Joint Surg Am.* 2000;82(1):26–34. <http://dx.doi.org/10.2106/00004623-200001000-00004>. Medline:10653081
- Fevang BT, Lygre SH, Bertelsen G, et al. Good function after shoulder arthroplasty. *Acta Orthop.* 2012;83(5):467–73. <http://dx.doi.org/10.3109/17453674.2012.720118>. Medline:22950481
- Fevang BT, Lie SA, Havelin LI, et al. Risk factors for revision after shoulder arthroplasty: 1,825 shoulder arthroplasties from the Norwegian Arthroplasty Register. *Acta Orthop.* 2009;80(1):83–91. <http://dx.doi.org/10.1080/17453670902805098>. Medline:19297791
- Hettrich CM, Weldon E III, Boorman RS, et al. Preoperative factors associated with improvements in shoulder function after humeral hemiarthroplasty. *J Bone Joint Surg Am.* 2004;86-A(7):1446–51. <http://dx.doi.org/10.2106/00004623-200407000-00012>. Medline:15252091
- Bjørnholdt KT, Brandsborg B, Søballe K, et al. Persistent pain is common 1–2 years after shoulder replacement. *Acta Orthop.* 2015;86(1):71–7. <http://dx.doi.org/10.3109/17453674.2014.987065>. Medline:25409254
- Schaible HG, Ebersberger A, Natura G. Update on peripheral mechanisms of pain: beyond prostaglandins and cytokines. *Arthritis Res Ther.* 2011;13(2):210. <http://dx.doi.org/10.1186/ar3305>. Medline:21542894
- Schaible HG. Pathophysiologie des schmerzes [Pathophysiology of pain]. *Orthopade.* 2007;36(1):8, 10–2, 14–6. Medline:17106742.
- Schaible HG. Peripheral and central mechanisms of pain generation. *Handb Exp Pharmacol.* 2007;(177):3–28. Medline:17087118.
- Omoigui S. The biochemical origin of pain: the origin of all pain is inflammation and the inflammatory response. Part 2 of 3— inflammatory profile of pain syndromes. *Med Hypotheses.* 2007;69(6):1169–78. <http://dx.doi.org/10.1016/j.mehy.2007.06.033>. Medline:17728071
- Omoigui S. The biochemical origin of pain—proposing a new law of pain: the origin of all pain is inflammation and the inflammatory response. Part 1 of 3—a unifying law of pain. *Med Hypotheses.* 2007;69(1):70–82. <http://dx.doi.org/10.1016/j.mehy.2006.11.028>. Medline:17240081
- Bouhassira D, Attal N. Diagnosis and assessment of neuropathic pain: the saga of clinical tools. *Pain.* 2011;152(3 Suppl):S74–83. <http://dx.doi.org/10.1016/j.pain.2010.11.027>. Medline:21185120
- Lin CP, Kupper AE, Gammaitoni AR, et al. Frequency of chronic pain descriptors: implications for assessment of pain quality. *Eur J Pain.* 2011;15(6):628–33. <http://dx.doi.org/10.1016/j.ejpain.2010.11.006>. Medline:21216641
- Cruccu G, Sommer C, Anand P, et al. EFNS guidelines on neuropathic pain assessment: revised 2009. *Eur J Neurol.* 2010;17(8):1010–8. <http://dx.doi.org/10.1111/j.1468-1331.2010.02969.x>. Medline:20298428
- Dworkin RH. Introduction: recommendations for the diagnosis, assessment, and treatment of neuropathic pain. *Am J Med.* 2009;122(10 Suppl):S1–2. <http://dx.doi.org/10.1016/j.amjmed.2009.04.004>. Medline:19801047
- Valdes AM, Suokas AK, Doherty SA, et al. History of knee surgery is associated with higher prevalence of neuropathic pain-like symptoms in patients with severe osteoarthritis of the knee. *Semin Arthritis Rheum.* 2014;43(5):588–92. <http://dx.doi.org/10.1016/j.semarthrit.2013.10.001>. Medline:24188720
- Schaible HG. Mechanisms of chronic pain in osteoarthritis. *Curr Rheumatol Rep.* 2012;14(6):549–56. <http://dx.doi.org/10.1007/s11926-012-0279-x>. Medline:22798062
- Oteo-Alvaro A, Ruiz-Iban MA, Miguens X, et al. High prevalence of neuropathic pain features in patients with knee osteoarthritis: A cross-sectional study. *Pain Pract.* 2015;15(7):618–26. <http://dx.doi.org/10.1111/papr.12220>. Medline:24750662
- Harden RN, Bruehl S, Stanos S, et al. Prospective examination of pain-related and psychological predictors of CRPS-like phenomena following total knee arthroplasty: a preliminary study. *Pain.* 2003;106(3):393–400. <http://dx.doi.org/10.1016/j.pain.2003.08.009>. Medline:14659522
- Haroutiunian S, Nikolajsen L, Finnerup NB, et al. The neuropathic component in persistent postsurgical pain: a systematic literature review. *Pain.* 2013;154(1):95–102. <http://dx.doi.org/10.1016/j.pain.2012.09.010>. Medline:23273105
- Wylde V, Jeffery A, Dieppe P, et al. The assessment of persistent pain after joint replacement. *Osteoarthritis Cartilage.* 2012;20(2):102–5. <http://dx.doi.org/10.1016/j.joca.2011.11.011>. Medline:22178464
- Razmjou H, Boljanovic D, Wright S, et al. Association between neuropathic pain and reported disability after total knee arthroplasty. *Physiother Can.* 2015;67(4):311–8. <http://dx.doi.org/10.3138/ptc.2014-46>. Medline:27504030
- Boljanovic-Susic D. Prevalence of postoperative chronic pain after total hip or knee arthroplasty [thesis]. Hamilton (ON): McMaster University Library; 2012 [cited 2017 Nov. 10]. Available from : <https://macsphere.mcmaster.ca/handle/11375/12670>.
- Bouhassira D, Attal N, Alchaar H, et al. Comparison of pain syndromes associated with nervous or somatic lesions and development of a new neuropathic pain diagnostic questionnaire

- (DN4). *Pain*. 2005;114(1-2):29–36. <http://dx.doi.org/10.1016/j.pain.2004.12.010>. Medline:15733628
29. Pérez C, Navarro A, Saldaña MT, et al. Modeling the predictive value of pain intensity on costs and resources utilization in patients with peripheral neuropathic pain. *Clin J Pain*. 2015;31(3):273–9. <http://dx.doi.org/10.1097/AJP.000000000000110>.
 30. O'Connor AB. Neuropathic pain: quality-of-life impact, costs and cost effectiveness of therapy. *Pharmacoeconomics*. 2009;27(2):95–112. <http://dx.doi.org/10.2165/00019053-200927020-00002>. Medline:19254044
 31. Constant CR. An evaluation of the Constant-Murley shoulder assessment. *J Bone Joint Surg Br*. 1997;79(4):695–6. Medline:9250770.
 32. Bennett MI, Smith BH, Torrance N, et al. The S-LANSS score for identifying pain of predominantly neuropathic origin: validation for use in clinical and postal research. *J Pain*. 2005;6(3):149–58. <http://dx.doi.org/10.1016/j.jpain.2004.11.007>. Medline:15772908
 33. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. 2001;16(9):606–13. <http://dx.doi.org/10.1046/j.1525-1497.2001.016009606.x>. Medline:11556941
 34. Attal N, Bouhassira D, Baron R, et al. Assessing symptom profiles in neuropathic pain clinical trials: can it improve outcome? *Eur J Pain*. 2011;15(5):441–3. <http://dx.doi.org/10.1016/j.ejpain.2011.03.005>. Medline:21458336
 35. Bennett GJ. Neuropathic pain: a crisis of definition? *Anesth Analg*. 2003;97(3):619–20. <http://dx.doi.org/10.1213/01.ANE.0000081724.18956.D9>. Medline:12933371
 36. Jensen MP, Chodroff MJ, Dworkin RH. The impact of neuropathic pain on health-related quality of life: review and implications. *Neurology*. 2007;68(15):1178–82. <http://dx.doi.org/10.1212/01.wnl.0000259085.61898.9e>. Medline:17420400
 37. Rosemann T, Joos S, Szecsenyi J, et al. Health service utilization patterns of primary care patients with osteoarthritis. *BMC Health Serv Res*. 2007;7(1):169. <http://dx.doi.org/10.1186/1472-6963-7-169>. Medline:17956605
 38. Rosemann T, Kuehlein T, Laux G, et al. Factors associated with physical activity of patients with osteoarthritis of the lower limb. *J Eval Clin Pract*. 2008;14(2):288–93. <http://dx.doi.org/10.1111/j.1365-2753.2007.00852.x>. Medline:18324933
 39. Rosemann T, Kuehlein T, Laux G, et al. Osteoarthritis of the knee and hip: a comparison of factors associated with physical activity. *Clin Rheumatol*. 2007;26(11):1811–7. <http://dx.doi.org/10.1007/s10067-007-0579-0>. Medline:17332977
 40. Kroenke K, Spitzer RL, Williams JB, et al. The patient health questionnaire somatic, anxiety, and depressive symptom scales: A systematic review. *Gen Hosp Psychiatry*. 2010;32(4):345–59. <http://dx.doi.org/10.1016/j.genhosppsych.2010.03.006>. Medline:20633738
 41. Damush TM, Wu J, Bair MJ, et al. Self-management practices among primary care patients with musculoskeletal pain and depression. *J Behav Med*. 2008;31(4):301–7. <http://dx.doi.org/10.1007/s10865-008-9156-5>. Medline:18553130
 42. Daniel W. Biostatistics: a foundation for analysis in the health sciences. 7th ed. New York: Wiley; 1999.
 43. Sauerland S, Lefering R, Bayer-Sandow T, et al. Fingers, hands or patients? The concept of independent observations. *J Hand Surg Br*. 2003;28(2):102–5. [http://dx.doi.org/10.1016/S0266-7681\(02\)00360-1](http://dx.doi.org/10.1016/S0266-7681(02)00360-1). Medline:12631478
 44. Louis TA, Lavori PW, Bailar JC III, et al. Crossover and self-controlled designs in clinical research. *N Engl J Med*. 1984;310(1):24–31. <http://dx.doi.org/10.1056/NEJM198401053100106>. Medline:6689736
 45. Park MS, Kim SJ, Chung CY, et al. Statistical consideration for bilateral cases in orthopaedic research. *J Bone Joint Surg Am*. 2010;92(8):1732–7. <http://dx.doi.org/10.2106/JBJS.I.00724>. Medline:20660236
 46. Bryant D, Havey TC, Roberts R, et al. How many patients? How many limbs? Analysis of patients or limbs in the orthopaedic literature: a systematic review. *J Bone Joint Surg Am*. 2006;88(1):41–5. Medline:16391248.
 47. Lädermann A, Lübbecke A, Mélis B, et al. Prevalence of neurologic lesions after total shoulder arthroplasty. *J Bone Joint Surg Am*. 2011;93(14):1288–93. <http://dx.doi.org/10.2106/JBJS.J.00369>. Medline:21792494
 48. Ahearn N, McCann PA, Tasker A, et al. The influence of rotator cuff pathology on functional outcome in total shoulder replacement. *Int J Shoulder Surg*. 2013;7(4):127–31. <http://dx.doi.org/10.4103/0973-6042.123509>. Medline:24403759
 49. Walch G, Badet R, Boulahia A, et al. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty*. 1999;14(6):756–60. [http://dx.doi.org/10.1016/S0883-5403\(99\)90232-2](http://dx.doi.org/10.1016/S0883-5403(99)90232-2). Medline:10512449
 50. Scarlat MM. Complications with reverse total shoulder arthroplasty and recent evolutions. *Int Orthop*. 2013;37(5):843–51. <http://dx.doi.org/10.1007/s00264-013-1832-6>. Medline:23456086
 51. Levy J, Frankle M, Mighell M, et al. The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture. *J Bone Joint Surg Am*. 2007;89(2):292–300. Medline:17272443.
 52. Van Hoof T, Gomes GT, Audenaert E, et al. 3D computerized model for measuring strain and displacement of the brachial plexus following placement of reverse shoulder prosthesis. *Anat Rec (Hoboken)*. 2008;291(9):1173–85. <http://dx.doi.org/10.1002/ar.20735>. Medline:18536051
 53. Nagda SH, Rogers KJ, Sestokas AK, et al. Neer Award 2005: peripheral nerve function during shoulder arthroplasty using intraoperative nerve monitoring. *J Shoulder Elbow Surg*. 2007;16(3 Suppl):S2–8. <http://dx.doi.org/10.1016/j.jse.2006.01.016>. Medline:17493556
 54. Cheung E, Willis M, Walker M, et al. Complications in reverse total shoulder arthroplasty. *J Am Acad Orthop Surg*. 2011;19(7):439–49. <http://dx.doi.org/10.5435/00124635-201107000-00007>. Medline:21724923
 55. Sviggum HP, Jacob AK, Mantilla CB, et al. Perioperative nerve injury after total shoulder arthroplasty: assessment of risk after regional anesthesia. *Reg Anesth Pain Med*. 2012;37(5):490–4. <http://dx.doi.org/10.1097/AAP.0b013e31825c258b>. Medline:22705952
 56. Lynch NM, Cofield RH, Silbert PL, et al. Neurologic complications after total shoulder arthroplasty. *J Shoulder Elbow Surg*. 1996;5(1):53–61. [http://dx.doi.org/10.1016/S1058-2746\(96\)80031-0](http://dx.doi.org/10.1016/S1058-2746(96)80031-0). Medline:8919443
 57. Guery J, Favard L, Sirveaux F, et al. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg Am*. 2006;88(8):1742–7. Medline:16882896.
 58. Bouhassira D, Letanoux M, Hartemann A. Chronic pain with neuropathic characteristics in diabetic patients: a French cross-sectional study. *PLoS One*. 2013;8(9):e74195. <http://dx.doi.org/10.1371/journal.pone.0074195>. Medline:24058527
 59. Bouhassira D, Lantéri-Minet M, Attal N, et al. Prevalence of chronic pain with neuropathic characteristics in the general population. *Pain*. 2008;136(3):380–7. <http://dx.doi.org/10.1016/j.jpain.2007.08.013>. Medline:17888574
 60. Attal N, Perrot S, Fermanian J, et al. The neuropathic components of chronic low back pain: a prospective multicenter study using the DN4 Questionnaire. *J Pain*. 2011;12(10):1080–7. <http://dx.doi.org/10.1016/j.jpain.2011.05.006>. Medline:21783428
 61. Walsh J, Rabey MI, Hall TM. Agreement and correlation between the Self-Report Leeds Assessment of Neuropathic Symptoms and Signs and Douleur Neuropathique 4 Questions neuropathic pain screening tools in subjects with low back-related leg pain. *J Manipulative Physiol Ther*. 2012;35(3):196–202. <http://dx.doi.org/10.1016/j.jmpt.2012.02.001>. Medline:22397741
 62. Pinto PR, McIntyre T, Ferrero R, et al. Persistent pain after total knee or hip arthroplasty: differential study of prevalence, nature, and

- impact. *J Pain Res.* 2013;6:691–703. <http://dx.doi.org/10.2147/JPR.S45827>. Medline:24072977
63. Lavand'homme PM, Grosu I, France MN, et al. Pain trajectories identify patients at risk of persistent pain after knee arthroplasty: an observational study. *Clin Orthop Relat Res.* 2014;472(5):1409–15. <http://dx.doi.org/10.1007/s11999-013-3389-5>. Medline:24258688
 64. Phillips JR, Hopwood B, Arthur C, et al. The natural history of pain and neuropathic pain after knee replacement: a prospective cohort study of the point prevalence of pain and neuropathic pain to a minimum three-year follow-up. *Bone Joint J.* 2014;96-B(9):1227–33. <http://dx.doi.org/10.1302/0301-620X.96B9.33756>. Medline:25183595
 65. Farmer KW, Hammond JW, Queale WS, et al. Shoulder arthroplasty versus hip and knee arthroplasties: a comparison of outcomes. *Clin Orthop Relat Res.* 2007;455:183–9. <http://dx.doi.org/10.1097/01.blo.0000238839.26423.8d>. Medline:16980898
 66. Fehringer EV, Mikuls TR, Michaud KD, et al. Shoulder arthroplasties have fewer complications than hip or knee arthroplasties in US veterans. *Clin Orthop Relat Res.* 2010;468(3):717–22. <http://dx.doi.org/10.1007/s11999-009-0996-2>. Medline:19626383
 67. Vissers MM, Bussmann JB, Verhaar JA, et al. Psychological factors affecting the outcome of total hip and knee arthroplasty: a systematic review. *Semin Arthritis Rheum.* 2012;41(4):576–88. <http://dx.doi.org/10.1016/j.semarthrit.2011.07.003>. Medline:22035624
 68. Masselin-Dubois A, Attal N, Fletcher D, et al. Are psychological predictors of chronic postsurgical pain dependent on the surgical model? A comparison of total knee arthroplasty and breast surgery for cancer. *J Pain.* 2013;14(8):854–64. <http://dx.doi.org/10.1016/j.jpain.2013.02.013>. Medline:23685186
 69. Suokas AK, Walsh DA, McWilliams DF, et al. Quantitative sensory testing in painful osteoarthritis: a systematic review and meta-analysis. *Osteoarthritis Cartilage.* 2012;20(10):1075–85. <http://dx.doi.org/10.1016/j.joca.2012.06.009>. Medline:22796624
 70. Mease PJ, Hanna S, Frakes EP, et al. Pain mechanisms in osteoarthritis: understanding the role of central pain and current approaches to its treatment. *J Rheumatol.* 2011;38(8):1546–51. <http://dx.doi.org/10.3899/jrheum.100759>. Medline:21632678
 71. Murphy SL, Phillips K, Williams DA, et al. The role of the central nervous system in osteoarthritis pain and implications for rehabilitation. *Curr Rheumatol Rep.* 2012;14(6):576–82. <http://dx.doi.org/10.1007/s11926-012-0285-z>. Medline:22879060
 72. Ohtori S, Orita S, Yamashita M, et al. Existence of a neuropathic pain component in patients with osteoarthritis of the knee. *Yonsei Med J.* 2012;53(4):801–5. <http://dx.doi.org/10.3349/ymj.2012.53.4.801>. Medline:22665349
 73. Orita S, Koshi T, Mitsuka T, et al. Associations between proinflammatory cytokines in the synovial fluid and radiographic grading and pain-related scores in 47 consecutive patients with osteoarthritis of the knee. *BMC Musculoskelet Disord.* 2011;12(144):144. Medline:21714933.
 74. Razmjou H, Schwartz CE, Holtby R. The impact of response shift on perceived disability two years following rotator cuff surgery. *J Bone Joint Surg Am.* 2010;92(12):2178–86. <http://dx.doi.org/10.2106/JBJS.I.00990>. Medline:20844160
 75. Finkelstein JA, Razmjou H, Schwartz CE. Response shift and outcome assessment in orthopedic surgery: is there a difference between complete and partial treatment? *J Clin Epidemiol.* 2009;62(11):1189–90. <http://dx.doi.org/10.1016/j.jclinepi.2009.03.022>. Medline:19679446