

Shoulder Double Crush Syndrome: A Retrospective Study of Patients With Concomitant Suprascapular Neuropathy and Cervical Radiculopathy

Yoshihiro Katsuura¹, Katherine Yao², Eric Chang³ , Tareck A Kadrie⁴ and John A Dorizas⁵

¹Department of Orthopaedic Surgery, The University of Tennessee College of Medicine Chattanooga, Chattanooga, TN, USA. ²Weill Cornell Medical, New York, NY, USA. ³School of Medicine, Tulane University, New Orleans, LA, USA. ⁴The Chattanooga Heart Institute Memorial Hospital, Chattanooga, TN, USA. ⁵Erlanger Sports and Health Institute, Chattanooga, TN, USA.

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ABSTRACT

PURPOSE: While the double crush phenomena (compression along two points on a nerve) has been established between median neuropathy and cervical radiculopathy, combined suprascapular neuropathy (SSN) and cervical C5/C6 radiculopathy—so-called shoulder double crush syndrome—has not been well examined. We aim to identify the incidence of shoulder double crush syndrome in patients undergoing arthroscopic suprascapular nerve release for SSN.

METHODS: One hundred consecutive patients >18 years of age who were positive for SSN on electromyography and motor nerve conduction studies (EMG/NCS) and underwent a suprascapular nerve release were included. Patients with evidence of shoulder double crush syndrome were identified based on x ray, cervical spine magnetic resonance imaging (MRI) and examination findings. Demographics, electrodiagnostics results, treatment courses, and clinical outcomes (visual analog scores and rotator cuff strength) following arthroscopic suprascapular nerve release were compared between patients with double crush syndrome versus isolated SSN.

RESULTS: Thirty one percent of patients had evidence of shoulder crush syndrome. Two significant electrophysiologic differences were noted in shoulder double crush patients compared to isolated SSN patients. Patients with double crush had an increased incidence of median neuropathy (51% vs 30%, $P = .04$). Double crush patients had less supraspinatus motor amplitude difference between the affected side and non-affected side compared to isolated SSN patients (2.62 mV vs 3.44 mV, $P = .03$). In general, most double crush patients were treated conservatively with regard to their cervical spine pathology.

CONCLUSION: A significant percentage of patients with SSN have evidence of shoulder double crush syndrome. Patients with SSN and concomitant median neuropathy should have a detailed neck examination performed.

KEYWORDS: Suprascapular neuropathy, double crush, cervical foraminal stenosis, cervical radiculopathy, median neuropathy, carpal tunnel syndrome

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CORRESPONDING AUTHOR: Yoshihiro Katsuura, Hospital for Special Surgery, 541 East 71st Street, 4th Floor, New York, NY 10021, USA. Email: yoshikatsuura@gmail.com

Introduction

The shoulder joint is controlled by a complex neuromuscular system that allows a wide range of function. The primary neurological input and output originates from the C5 and C6 cervical nerve roots, which through the suprascapular nerve, control a dominant portion of motor and sensory function of the shoulder.^{1–3}

Clinicians are increasingly identifying suprascapular neuropathy (SSN) as a common cause of shoulder pain and recognizing arthroscopic decompression as a viable treatment method.^{4,5} In addition, patients with cervical spondylosis affecting the C5 nerve root more commonly have shoulder pathology.^{4,6}

The term double crush, originally coined by Upton and McComas⁷ refers to compression of a peripheral nerve at two points along its course.⁸ The central component of this theory is that proximal compression makes the distal nerve more

susceptible to injury due to a disruption in axonal flow.^{9,10} Double crush syndrome occurring between the cervical spine and the median nerve has been well documented occurring at a rate of 18%^{8,11,12} with C5 and C6 being the most commonly affected nerve roots.⁸ Importantly, 30% of median nerve double crush patients considered their carpal tunnel release a failure, which may be likely related to persistent foraminal stenosis.⁸ Approximately 30% of all patients with SSN have concomitant signs of other neurologic injury in the cervical spine.⁴ Nonetheless, double crush syndrome of the suprascapular nerve and C5 and C6 radiculopathy has not been well studied. To our knowledge, there have been no case series examining shoulder double crush patients undergoing arthroscopic or any other minimally invasive suprascapular nerve releases.

The purpose of this study was to identify patients who had clinical evidence of double crush syndrome of the suprascapular



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nerve and cervical spinal roots and to study their clinic characteristics, their electrodiagnostics findings, and finally their treatment outcomes with arthroscopic SSN nerve release compared to patients with isolated SSN. We hypothesize that this pattern of double crush syndrome is an underdiagnosed phenomenon.

Methods

After institutional review board approval, a retrospective review of the electronic medical record of a tertiary referral care hospital center was undertaken to examine the clinical courses of patients treated consecutively between 2013 and 2014 with arthroscopic suprascapular nerve decompression. The etiology of SSN in our cohort was compressive entrapment at the suprascapular notch. Patients ≥ 18 years old were included if they had pre- and post-operative visual analog scale (VAS) scores available, pre- and post-operative strength testing performed, were positive for SSN on electromyography and motor nerve conduction studies (EMG/NCS) and had a magnetic resonance image (MRI) of the operative shoulder prior to surgery. Patients were excluded if they lacked a diagnosis of SSN based on EMG/NCS testing or were under the age of 18. Patients were also excluded if they had a concomitant diagnosis of brachial plexopathy, thoracic outlet syndrome or long thoracic nerve dysfunction.

Patient demographics collected included age, gender, diabetic status, workers compensation status, smoking status, and whether or not they required a concomitant rotator cuff repair at the time of SSN release. Clinical information collected included VAS pain scores, scored on a scale of 0 to 10, collected on the first clinical visit preoperatively and on the patient's final post-operative follow-up visit. Shoulder examination was performed by the senior author pre- and post-operatively on all patients and consisted of grading the strength of the supraspinatus (SS) and infraspinatus (IS) on the manual muscle test scale of 0 to 5 (5: antigravity + maximal resistance, 4: antigravity + moderate resistance, 3: antigravity alone, 2: movement with gravity eliminated, 1: trace movement, and 0: no movement). SS muscle strength was evaluated with the empty can test: resisted shoulder abduction at 90 degrees with 60° forward flexion, with arms pronated to isolate the muscle bilaterally. Care was taken to ensure the scapula was in a retracted position, to prevent scapular protraction from falsely demonstrating weakness. The IS muscle was graded by the external rotation strength test: the shoulders were fully adducted and placed with 10° flexion, elbows flexed to 90°, and shoulder external rotation strength tested at 15°–20° of external rotation bilaterally. In both muscles, the strength was graded and compared to the contralateral side simultaneously and conducted twice by the senior author to maximize precision and accuracy.

Shoulder magnetic resonance images (MRIs) were evaluated specifically for rotator cuff pathology. If concomitant cervical radiculopathy was suspected with history (pain radiating down to or past the elbow with associated numbness and

paresthesias) or exam (positive Spurling's test or shoulder abduction test) MRI or x-ray imaging was obtained of the cervical spine. The Spurling's test was considered positive if the patient's pain was recreated with an axial loading force was applied to an extended and ipsilaterally rotated head to the side of symptoms. Patients were considered to have double crush syndrome if they had both a positive clinical picture (history and exam findings) and C5 or C6 foraminal stenosis/canal stenosis on X-ray, MRI or positive C5 or C6 radiculopathy on EMG/NCS. Foraminal stenosis was defined according to MRI classification system proposed by Kim et al¹³ and considered stenotic if there was $>50\%$ narrowing of the foramen, diagnosed by both a board certified radiologist and the senior author. Three of 31 double crush patients did not have their cervical MRIs available on the institution's PACS but were included in this group because of clear bony neuroforaminal stenosis and disk height loss on oblique cervical spine x-rays at the C5 and C6 nerve root levels. There is evidence that plain radiographs of foraminal stenosis on oblique x-rays, particularly in severe grade range (as was the case with our three patients), corresponds with advanced imaging techniques.¹⁴

Electrophysiologic examination

All electrophysiological studies were performed prior to surgical decompression by a single electromyography/neurophysiology fellowship trained neurologist with 14 years' experience. EMG studies were performed based on indication for EMG referral by managing physician and the neurologist had no knowledge of this particular study. Suprascapular nerve motor conduction studies were performed stimulating at Erbs point and measuring at the SS using surface electrodes. Contralateral studies were performed on all studies for comparison. A side-to-side motor onset latency difference of >0.5 ms and compound muscle action potential (CMAP) amplitude changes of 50 percent or greater were considered significant. These cutoffs are considered standard for the diagnosis of SSN.^{15,16}

EMG was performed on cervical paraspinal muscles, multiple shoulder girdle muscles and multiple upper extremity distal muscles. The findings of abnormal spontaneous activity (increased insertional activity, fibrillations, or positive waves) were considered significant, as were motor unit action potential (MUAP) amplitude or duration changes, and decreased recruitment. SSN patients had changes confined to the SS and IS, while standard criteria were utilized to diagnose concomitant or isolated cervical radiculopathy. No bilateral EMG changes were noted.

Statistical methods

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software (IBM, Version 24.0, Chicago, USA). The dependent *t*-test was used to compare means between continuous variables within the same group

Table 1. Demographics and outcomes of double crush and isolated SSN patients who underwent arthroscopic SSN decompression.

	ALL PATIENTS	ISOLATED SSN	DOUBLE CRUSH	P-VALUE
N	100	69	31	
Number of female	55	36	19	
Mean age (range), years	53.1 (21-75)	51 (21-73)	57.8 (36-75) ($P=.23$)	.023
Average time of symptoms prior to initial clinic presentation (months)	20.5	22.19	16.71	.48
Average follow-up (months)	8.81	8.49	10.32 ($P=.36$)	.36
Diabetes	10 (10%)	7 (10%)	3 (10%)	1.0
Past or current smoker	36 (36%)	21 (30%)	8 (26%)	.84
Workers comp	20 (20%)	12 (16%)	11(25%) ($P=.24$)	.24
BMI	28.8	28.83	28.75	.94
Concomitant RCR	25	17 (24%)	8 (26%)	.8

BMI: body mass index; RCR: rotator cuff repair; SSN: suprascapular neuropathy.

(ie, initial and final VAS scores). The independent *t*-test was used to compare means between continuous variables of different groups (ie, between the double crush and isolated SSN patients). A paired chi-square test was used to compare ordinal variables between the double crush and isolated SSN patients.

Results

Patient demographics

In all, 162 patients underwent arthroscopic decompression of their suprascapular nerve during the study period, of which 62 were excluded (based on having incomplete imaging, clinical or neurophysiological records as described above), yielding 100 patients who were included in this study (female = 55). Overall there were 31 double crush patients and 69 isolated SSN patients. Average age of participants was 53 years, and there was a significant difference in age between the two groups (isolated, 51 years vs double crush, 57 years, $P=.02$). Patients had an average duration of symptoms for 20 months prior to presentation in clinic and an average follow-up timeframe of 8.8 months after surgery. All patients presented with posterior shoulder pain and weakness of the rotator cuff. Comorbidities were similar between the two groups. Double crush patients had a higher rate of workman's compensation claims (25%) compared to the isolated SSN group (16%); however, the difference was not statistically significant ($P=.24$). The rate of rotator cuff pathology requiring surgical repair was similar for both groups (24% vs 26%, $P=.8$) (Table 1).

Concomitant cervical treatments and procedures for double crush patients

About one-half of the double crush patients did not require a separate cervical procedure ($n=16$, 51%). There were seven

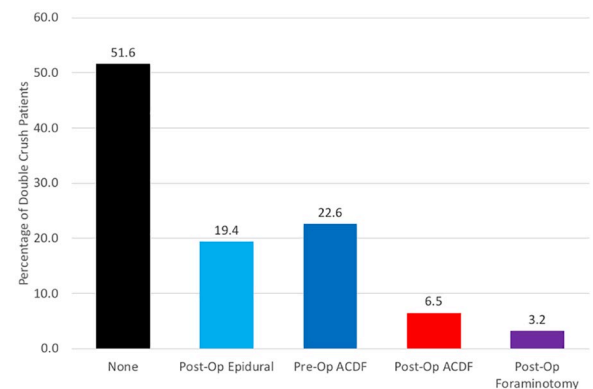


Figure 1. Cervical procedures performed on double crush patients before or after their suprascapular nerve release. ACDF: anterior cervical disk fusion.

patients (25%) who had anterior cervical discectomy and fusion (ACDF) performed before their suprascapular nerve release. There were two patients (6.4%) who required ACDF after their suprascapular nerve release. There were six patients (19%) who required epidural injections in isolation after SSN release (Figure 1).

Clinical outcomes

Overall, there was a statistically significant decrease in VAS pain scores for all patients who underwent arthroscopic SSN decompression (both isolated and double crush SSN) from initial presentation ($M=6.52$, $SD=1.94$) to final follow-up ($M=3.01$, $SD=2.4$), $t(200)=11.41$, $P<.0001$. Moreover, there were statistically significant improvements in SS strength on manual muscle testing (MMT) in all patients from pre-op ($M=3.27$, $SD=0.60$) and post-op ($M=4.93$, $SD=0.23$, $P<.0001$), and IS strength from preop ($M=3.34$, $SD=0.64$) and post op ($M=4.79$, $SD=0.43$, $P<.0001$) (Figure 2/Table 2).

There was no significant difference between VAS outcomes between double crush patients ($M=3.03$, $SD=3.15$) and isolated SSN patients ($M=3.73$, $SD=2.62$), $t(99)=1.15$, $P=.25$. There were nine patients who had a cervical procedure either before or after their SSN release, as described above. Double crush patients who had a cervical spine intervention generally had worse VAS improvement ($M=2.78$, $SD=2.99$), but this difference was not significant ($P=.31$) (Figure 2/Table 2).

There was no significant difference between SS or IS MMT strength improvement between double crush patients (SS: $M=1.71$, $SD=0.57$, IS: $M=1.46$, $SD=0.74$) and isolated SSN patients (SS: $M=1.61$, $SD=0.64$; IS: $M=1.44$, $SD=0.77$), (SS: $P=.47$; IS: $P=.88$). Patients who had double crush injuries and underwent cervical spine surgical interventions did not demonstrate any significant differences in strength improvement (SS: $M=1.551$, $SD=0.68$, IS: $M=1.0$, $SD=0.86$) compared to those with isolated SSN (SS: $P=.79$; IS: $P=.11$) (Table 2).

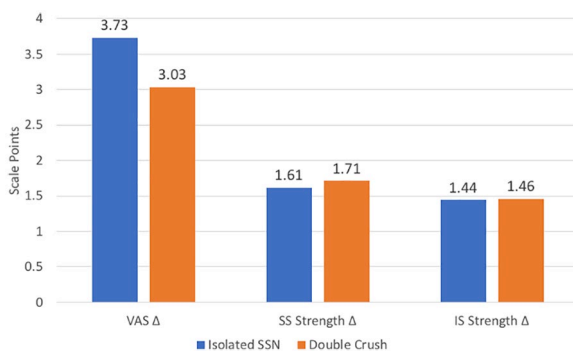


Figure 2. Changes in VAS scores, supraspinatus strength and infraspinatus strength pre- and post-op. Please note that VAS score changes were represented in positive numbers even though the change was actually negative. IS: infraspinatus; SS: supraspinatus; VAS: visual analog scale.

Electrophysiological evaluation

The overall rate of median neuropathy diagnosed by EMG/NCS was 37%. Patients with double crush had a significantly higher rate of median neuropathy (51%) on EMG/NCS studies compared to isolated SSN (30%), ($P=.04$) (Figure 3).

Two patients were excluded in the analysis of the nerve conduction studies due to incomplete EMG/NCS reports (one patient from the isolated group and one from the double crush group). The average suprascapular nerve motor onset latency for all patients in this study was 2.68 ms and the amplitude was 2.7 mV. All patients had evidence of active denervation on EMG (fibrillations and increased insertional activity) in the SS and/or IS muscles.

There was no significant difference in the measured suprascapular nerve CMAP amplitude on the affected side between double crush patients ($M=2.76$ mV, $SD=1.44$) compared to the isolated SSN group ($M=2.68$, $SD=1.02$), $t(97)=-0.32$, $P=.78$. However, there was a statistically significant difference found in the suprascapular nerve CMAP amplitude differences (amplitude contralateral side—amplitude affected side) between double crush patients ($M=2.61$ mV, $SD=1.62$) and isolated SSN patients ($M=3.44$, $SD=1.80$, $P=.03$). There was no significant difference in motor onset latency between double crush patients ($M=2.35$ ms, $SD=9.2$) compared to the isolated SSN group ($M=2.86$, $SD=1.46$, $P=.11$). Motor onset latency difference approached but did not reach statistical significance (motor onset latency contralateral side—motor onset latency affected side) between double crush patients ($M=0.79$ ms, $SD=0.78$) compared to the isolated SSN group ($M=1.18$, $SD=1.41$, $P=.15$) (Figure 4).

Discussion

SSN has been previously thought to be rare and a diagnosis of exclusion. However, studies on the subject have established it as a cause of shoulder pain with a higher prevalence in patients

Table 2. Examination results of double crush (DC) patients and isolated (ISO) suprascapular nerve patients.

	ISOLATED SSN	DOUBLE CRUSH	P-VALUE
Difference in VAS initial and VAS final	3.73 (6.46 → 2.72)	3.03 (6.68 → 3.65) ($P=.25$)	.25
Difference in SS strength Final and Initial	1.61	1.71 ($P=.47$)	.47
Difference in IS strength Final and Initial	1.44	1.46 ($P=.88$)	.88
Rate of concomitant median neuropathy on EMG/NCS	21 (31%)	16 (51.6%) ($P=.04$)	.04
Affected side SS nerve motor onset latency (ms)	2.82	2.35 ($P=.11$)	.11
Motor onset latency difference compared to contralateral SS nerve (ms)	1.18	0.78 ($P=.15$)	.15
Affected side SS nerve motor amplitude (mV)	2.76	2.68	.75
Non-affected side SS nerve motor amplitude (mV)	6.12	5.38	.10
SS nerve motor amplitude difference (mV)	3.44	2.62 ($P=.03$)	.03

EMG: electromyography; IS: infraspinatus; NCS: nerve conduction studies; SS: supraspinatus; SSN: suprascapular neuropathy; VAS: visual analog scale. Bold values shows $P < 0.05$ considered statistically significant.

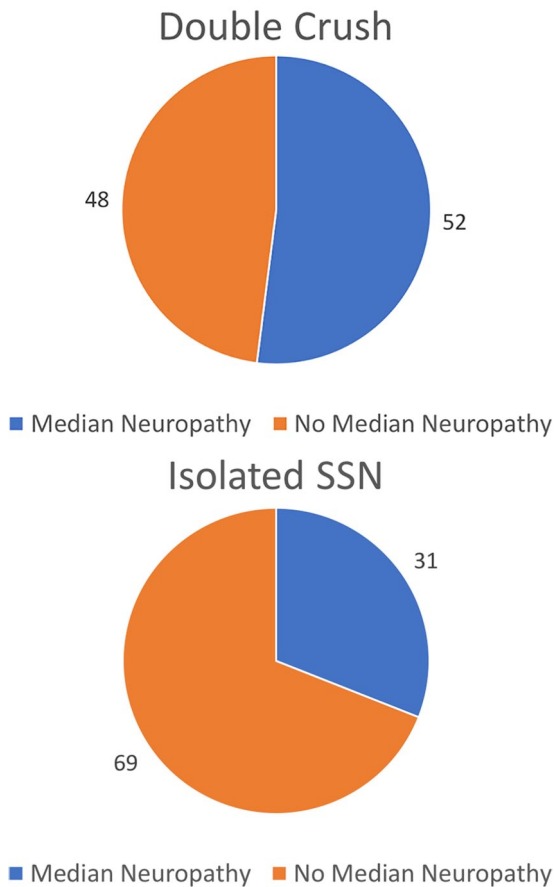


Figure 3. Percentage of double crush and suprascapular patients with median neuropathy on EMG/NCS. EMG: electromyography; NCS: nerve conduction studies; SSN: suprascapular neuropathy.

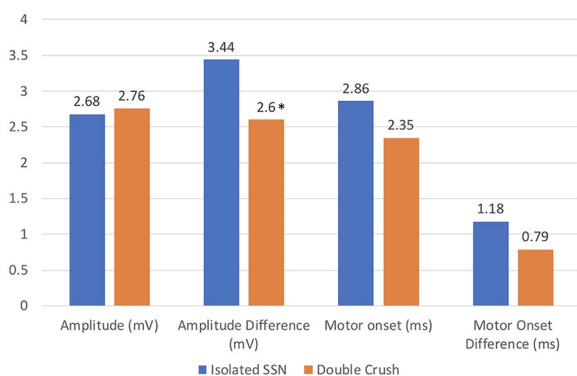


Figure 4. Amplitude and motor onset latency of the affected side of double crush patients and isolated suprascapular patients. The difference in amplitude and motor onset between the affected side and non-affected side for both isolated suprascapular nerve and double crush patients. SSN: suprascapular neuropathy.

with rotator cuff tears.^{4,17-19} There are many etiologies including hypertrophy of the transverse scapular ligament, labral cysts, varicose veins, retracted rotator cuff injuries, or traction injuries from overhead athletics.^{17,18,20-23} The suprascapular nerve is supplied in most cases solely by the C5 and C6 nerve roots.²⁴ Pathology in this area of the cervical spine can result in shoulder dysfunction and referred pain similar to SSN.

Boykin examined the incidence of SSN in a shoulder referral practice. Out of 92 patients with available studies, 42 had diagnosed SSN which amounted to 4% of new shoulder referrals and 43% of those who were suspected to have SSN (chronic aching posterior shoulder, atrophy or fatty infiltration of the SS, or massive rotator cuff tears). In this series, 32% of patients with SSN had a mixed pattern of additional findings on EMG/NCS (cervical radiculopathy, axillary neuropathy, or long thoracic neuropathy). There was a high incidence of concomitant rotator cuff pathology (54%). Only 33% of patients had EMG evidence of muscle denervation. The average motor latency of the SSN was 2.9 ms compared to 2.6 ms in non-diagnostic studies.⁴ This is similar to the average SS motor onset latencies in this study (SSN: 2.9 ms vs contralateral normals: 2.68 ms); however, there is considerable variability between centers.¹⁵

EMG/NCS studies may underestimate the presence of SSN due to the small caliber of the suprascapular nerve.²⁵ Normal electrodiagnostic values have been reported by several authors.^{15,26} Gassel²⁷ published normal values in 23 subjects for the SS distal latency as 2.6 ± 0.07 and 3.4 ± 0.09 ms for the IS. Buschbacher et al reported on the normal distal latency of the IS in 100 volunteers using surface electrodes at an average of 3.2 ms for the SS and 3.6 ms for the IS. The average amplitude for the SS was 3.7 ± 2.3 mV with a wide range (1.2-12.6 mV).

Double crush syndrome is defined by compression along a peripheral nerve at multiple points and these patients characteristically fail to improve after single site decompression surgery.^{7,8} Physiologically, dual points of constriction on a peripheral nerve have been shown in animal models to summate into more severe neurological derangements.^{9,28} Clinically, double crush syndrome is nebulous because it is difficult to ascribe a percentage of pain to each compression point.²⁹ Previous studies have shown an increased rate of median neuropathy in patients with cervical radiculopathy at a rate of 18%.⁸ Nonetheless, the syndrome remains incompletely understood and optimal treatment paths are unclear.²⁹ To our knowledge, there has only been one double crush case reported of combined C5 radiculopathy with SSN. In this case, the patient had an ACDF performed after a rotator cuff repair failed to provide relief. After these two surgeries the patient failed to fully improve and was eventually found to have a SSN that was successfully treated with decompression.³⁰ Our study highlights the importance of both neck and shoulder evaluation in patients with shoulder pain.

In this study, we found that a significant number of patients with double crush also had signs of median neuropathy on EMG/NCS. Considering the contributions from C5 and C6 to the median nerve, this finding is consistent with the overall physiology of double crush syndrome (ie, double crush patients have increased susceptibility to distal nerve compression lesions). Furthermore, there was a significant difference between isolated suprascapular nerve patients and double crush patients with regard to amplitude difference between the affected side and the

non-affected side. The double crush patients had less of a side-to-side difference, which may signify greater bilateral suprascapular nerve changes from cervical nerve root compression. Alternatively, it may signify that double crush patients had less significant injury to the suprascapular nerve. Motor onset latency difference approached but did not reach significance. It is possible that a higher powered series could detect this difference.

Recently there has been increasing evidence that cervical spine pathology causes rotator cuff tears.^{31,32} This is in part due to physiologic changes in the tendon structure after denervation.^{33,34} This study demonstrated a trend toward increasing rotator cuff pathology in double crush patients but this was not statistically significant ($P=.23$). These two populations, those with rotator cuff injuries with underlying cervical spine pathology versus double crush syndrome, are difficult to discern because all patients inherently had SSN and denervation of the rotator cuff. It is possible that larger numbers are needed to confirm this theory.

There have been several retrospective studies demonstrating the efficacy of both open and arthroscopic suprascapular nerve release.³⁵⁻³⁷ However, Shah et al³⁵ noted in their series of 24 arthroscopic suprascapular nerve decompressions that patients who failed to improve had evidence of cervical spine pathology. In this series, patients with both compression in the cervical foramen and at the suprascapular nerve had similar relief in pain from arthroscopic decompression and improvement in pain scores. There were 9 patients who underwent a cervical decompression and fusion procedure either before or after their suprascapular nerve release. They had a trend toward worse VAS outcomes but this did not reach significance. The majority of double crush patients received either no surgical cervical spine treatment or epidural injections in isolation.

Limitations

There are several limitations to this retrospective study. First, the diagnosis of shoulder double crush syndrome is difficult to make, and to our knowledge no criteria currently exists to aid in the diagnosis. For this reason, we devised a clinical criteria system to categorize these patients. All patients had to demonstrate a combination of clinical symptoms (positive Spurling's test, or positive upper extremity radiculopathy by history or exam) as well as either evidence of C5 and/or C6 foraminal or central stenosis on MRI or EMG/NCS evidence of C5/C6 radiculopathy. Unfortunately, in this study, three patients lacked documented cervical MRIs and the cervical stenosis diagnosis was made based on radiographs. Future research should examine all SSN patients with MRI to determine the true incidence of concomitant cervical spondylosis at C5 and C6. It should be noted that a significant number of patients with cervical foraminal and central stenosis noted on MRI are asymptomatic and thus in isolation may not indicate a double crush syndrome.^{38,39}

Another limitation was that our outcomes scores were limited to VAS and strength grading which can be highly

subjective and variable. We did not have follow-up EMG/NCS exams conducted post-operatively which may provide more quantitative and reliable outcome measures. Future prospective studies examining SSN should be performed to further clarify these problems.

Conclusion

In conclusion, patients with double crush syndrome involving the cervical spine and SSN demonstrate characteristic clinical findings of cervical radiculopathy (on history, exam, and radiologic imaging) and shoulder girdle weakness, have characteristics EMG/NCS findings, and may show improvement in symptoms with SSN decompression. They may have a decreased difference in suprascapular nerve CMAP amplitude between the affected side and the non-affected side making diagnosis of SSN more difficult. This is likely related to bilateral denervation of the suprascapular nerve from bilateral foraminal lesions. Moreover, they are more likely to have median neuropathy on EMG/NCS which fits the theoretical picture of a double crush syndrome. Physicians should be aware of and consider the possibility of double crush syndrome in patients with ill-defined shoulder pain and should carefully evaluate for neck pathology with any shoulder evaluation as there is significant overlap between neck and shoulder symptomatology.

Author's Note

Yoshihiro Katsuura is also affiliated with Hospital for Special Surgery, Department of Orthopaedic Surgery, NY, New York and Weill Cornell Medical College, NY, New York.

John A Dorizas is also affiliated with Department of Orthopaedic Surgery, The University of Tennessee College of Medicine Chattanooga, Chattanooga, TN, USA.

Tareck A Kadrie is also affiliated with Erlanger Sports and Health Institute, Chattanooga, TN, USA.

Author Contributions

All authors contributed equally to data collection and manuscript preparation.

ORCID ID

Eric Chang  <https://orcid.org/0000-0002-7496-1192>

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