## Title

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# Surgical decompression among Paget-Schroetter patients with subacute and chronic venous occlusion

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## ABSTRACT

**Objective:** Management of Paget-Schroetter syndrome (PSS) with first rib resection (FRR) and venoplasty is successful in re-establishing subclavian vein (SCV) patency in most cases. However, in cases with subacute or chronic venous occlusion, SCV patency may not be achieved. Thus, the role for FRR remains controversial in cases of subacute or chronic SCV occlusion. Our goal is to determine whether FRR is beneficial in PSS patients with subacute or chronic SCV occlusion.

**Methods:** A prospectively maintained thoracic outlet syndrome (TOS) database was searched for patients undergoing FRR who were identified as having SCV occlusion on preoperative venography between 2012 and 2021. Preoperative and postoperative venous patency were determined by venography. Standardized functional outcomes were assessed using the Quick Disability Arm, Shoulder, Hand (QuickDASH—QDS) and Somatic Pain Scale (SPS) before and after FRR. The Derkash outcome score was recorded after FRR.

**Results:** Over the study period, 966 TOS operations were performed; of these, 401 were for venous TOS, and 33 patients were identified with subacute or chronic preoperative SCV occlusion verified by venography. The median age was 29 years, with 73% men. Eighteen patients had attempted thrombolysis; eight were performed at our institution, and ten performed at a referring facility. The median time from the symptom onset of SCV occlusion to FRR was 78 days for all patients. For the group that achieved venous patency after FRR, the time from SCV occlusion to FRR was 71 days, and it was 106 days for the group that remained occluded after FRR. All underwent postoperative venography and percutaneous attempt at SCV recanalization. Recanalization was successful in 64% (21) and unsuccessful in 36% (12). All patients experienced improvement in SPS and QDS. For all patients, the average SPS improved from 1.69 preoperatively to 0.25 postoperatively and the average QDS improved from 27.63 preoperatively to 10.19 postoperatively ($P > .05$). For patients who were successfully recanalized, the final SPS was 0.18 and the final QDS was 11.22 ($P > .05$). In patients who failed to achieve recanalization, the final SPS was 0.40 and the final QDS was 9.06 ($P > .05$). All postoperative Derkash outcome scores were excellent and good, with none fair or poor.

**Conclusions:** In patients with subacute or chronic preoperative SCV occlusion, surgical decompression and postoperative angioplasty resulted in re-establishing SCV patency in 64% of patients. Symptomatic patients clinically improve after surgical decompression regardless of whether venous patency is successfully re-established. These results indicate that symptomatic patients with PSS should be considered for TOS decompression even if their SCV is occluded in the subacute or chronic presentation. (J Vasc Surg Venous Lymphat Disord 2022;10:1245-50.)

**Keywords:** Thoracic outlet; Venous; Pagett-Schroetter; Venogram; Occlusion

Spontaneous upper extremity deep venous thrombosis is rare and frequently associated with anatomic abnormalities of the thoracic outlet, causing extrinsic compression of the subclavian vein (SCV) and subsequent thrombosis. Paget-Schroetter syndrome (PSS) was first defined by Hughes in 1984, after the observations made and published by Sir Paget in 1875 and Von Schroetter in 1884.[1] PSS is relatively rare, with an annual incidence of approximately one to two cases per 100,000 individuals, and affects primarily younger patients in their twenties and thirties with a male predominance.[2] Patients present with upper extremity swelling and pain, typically with an antecedent strenuous activity before the development of symptoms.[3] Whereas some patients have an acute presentation within 2 weeks of the initial thrombosis, some patients are not diagnosed with PSS until weeks to months after the initial thrombotic event.

The initial treatment for PSS involves treatment of deep vein thrombosis with anticoagulation. Venography with pharmacomechanical thrombectomy or catheter-directed thrombolysis can also be performed for patients who present acutely with the goal of rapid symptom improvement and the reduction of overall thrombus burden.[4] This was reported in a landmark study by

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Machleder et al,[4] and later confirmed by Doyle and Lee.[5,6] The decision to treat with catheter-directed thrombolysis vs systemic anticoagulation before referral for surgical decompression is often influenced by local practice patterns. Thrombolysis has not been shown to offer an added benefit in restoring vein patency in patients who present more than 2 to 4 weeks after the onset of symptoms.[4-6] The physiologic rationale for surgery in venous thoracic outlet syndrome (TOS) is based on restoring venous patency by relief of extrinsic compression and restoration of the venous lumen. Surgical decompression may be accomplished by first rib resection (FRR) via a transaxillary, infraclavicular, or paraclavicular surgical approach.

Patients who present to our medical center with occluded SCVs have typically been managed with anticoagulation and attempt at endovascular recanalization. Although many of these procedures are successful in restoring SCV patency, there are a subset of patients who remain occluded. The role of surgical decompression for PSS for occluded SCVs is controversial. Prior studies by Urschel et al[7] and de León et al[8] have shown that some patients with occluded SCVs will re-establish patency after surgical decompression. Several significant questions remain regarding patients presenting with subacute and chronically occluded SCV: how often is SCV patency restored after surgical decompression? Is there symptomatic benefit to restoring patency? Is there a clinical benefit if patency is not restored? We sought to study these questions by studying the fate of patients presenting with subacute or chronic SCV occlusion who underwent FRR at our institution.

## ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center, retrospective cohort study
- **Key Findings:** In 33 patients with subacute or chronic preoperative subclavian vein occlusion, surgical decompression and postoperative angioplasty resulted in re-establishing subclavian vein patency in 64% of patients. All patients experienced improvement in standardized clinical outcome measures.
- **Take Home Message:** Patients demonstrated improvement in standardized clinical outcome measures after surgical decompression regardless of whether venous patency is successfully re-established. Symptomatic Paget-Schroetter patients with subacute or chronic subclavian vein occlusions should be considered for thoracic outlet decompression.

## METHODS

A retrospective review of a prospectively maintained TOS database was performed, identifying all patients with venous TOS who had occluded SCVs presenting between 2012 and 2021. Patients with symptomatic occlusion underwent ipsilateral FRR and postoperative venography at a single center. Patients with asymptomatic SCV occlusion or acute symptomatic SCV occlusion were excluded from analysis. Subacute venous thrombosis was defined as having occurred between 2 weeks and 3 months from symptom onset. Chronic venous thrombosis was defined as having occurred more than 3 months from symptom onset. We included only those patients who had assessment of SCV patency by catheter-directed venogram both before and after FRR. Vein patency was defined using venography as continuity of contrast flow in the SCV across the thoracic outlet. Patients with a patent SCV on preoperative venogram were excluded. Vein occlusion was defined as an interruption in the contrast flow across the thoracic outlet. Postoperative patients found to have stenosis greater than 50% luminal narrowing of the SCV on venogram after FRR were treated with balloon angioplasty. Recanalization of occluded SCVs was attempted for patients who remained occluded on venogram after FRR. Final vein patency status was determined by venography after endovascular intervention. Postoperative duplex was not used to establish patency of the SCV after FRR. All patients underwent staged postoperative venography approximately 2 to 3 weeks after FRR. FRR was accomplished via a standard transaxillary approach with delayed venography followed by anticoagulation for 3 months after FRR. A subset analysis for the presence of neurogenic symptoms by SCV patency before and after FRR was performed to assess for changes in concomitant neurogenic symptoms.

Patient data collected included gender, age, laterality, athletic participation, preoperative thrombolysis, initial onset of symptoms, presence of hypercoagulable disorder, interval between presentation to intervention, and duration of follow-up. Data were organized in accordance with SVS reporting standards.[9] Standardized clinical outcomes were obtained using the Quick Disability of Arm Hand Shoulder (QuickDASH Score—QDS), where a patient with no disability will score 0 and one who has maximal disability will score 100. Somatic Pain Scale (SPS), where a patient with no reported pain will score 0 and one with maximum pain intensity will score 10, was used both preoperatively and postoperatively. Derkash scores (DKS) of symptom severity were collected postoperatively. All patients were followed postoperatively at 6-week intervals for the first 3 months, and then 3-month intervals thereafter until symptom resolution or failure to return. The institutional review board approved the study and authorized permission to access these medical records (protocol no. 13-000624, UCLA IRB).

**Table I.** Patient demographic, presentation, management, time intervals (pre- and postoperative), and operative data are presented for all patients (All), patients whose subclavian vein (SCV) was patent at last postoperative follow-up (Patent), and patients whose SCV was occluded at last postoperative follow-up (Occluded)

| | All | Patent | Occluded | *P* value |
|---|---|---|---|---|
| Demographics | (n = 33) | (n = 21) | (n = 12) | |
| Age (median), years | 29.0 | 28.0 | 30.5 | n.s. |
| Women | 27.0% | 29.0% | 25.0% | n.s. |
| Right-sided | 79.0% | 81.0% | 75.0% | n.s. |
| Any sports activity | 69.7% | 71.4% | 66.7% | n.s. |
| Presentation | | | | |
| Pain/discomfort | 60.6% | 61.9% | 58.3% | n.s. |
| Discoloration | 42.4% | 38.1% | 50.0% | n.s. |
| Engorgement | 36.4% | 38.1% | 33.3% | n.s. |
| Numbness/tingling | 27.3% | 23.8% | 33.3% | n.s. |
| Management | | | | |
| Preoperative venogram | 100.0% | 100.0% | 100.0% | n.s. |
| Hematology evaluation | 36.4% | 38.1% | 33.3% | n.s. |
| Clotting disorder | 3.0% | 4.8% | 0.0% | n.s. |
| Preoperative | | | | |
| Onset of DVT to first clinic visit (median), days | 27 | 20 | 66.5 | n.s. |
| Onset of DVT to FRR (median), days | 78 | 71 | 106.5 | n.s. |
| DVT to FRR (max), days | | 3222 | 2455 | |
| DVT to FRR (standard deviation), days | | 689 | 683 | |
| Postoperative | | | | |
| FRR to venogram (median), days | 18 | 20 | 17 | n.s. |
| FRR to last clinic visit (median), days | 62 | 69 | 35.5 | n.s. |
| Treatment course | | | | |
| Estimated blood loss, mL | 25.9 | 26 | 25.7 | n.s. |
| Length of stay, days | 2.1 | 2.5 | 2.1 | n.s. |
| Postoperative complications | 0.0% | 0.0% | 0.0% | n.s. |
| Postoperative venogram | 100.0% | 100.0% | 100.0% | n.s. |

*DVT*, Deep vein thrombosis; *FRR*, first rib resection; *n.s.*, not statistically significant, $P > .05$, comparison between Patent and Occluded cohorts.

**Statistical analysis.** Categorical variables were analyzed using $\chi^2$ analysis. Continuous variables were analyzed with Student's *t*-test. Wilcoxon signed-rank test analysis was used to assess repeated measures for individual subjects. The Mann-Whitney *U* test was used to assess differences between repeated measurements between comparison groups. Significance was assigned at a $P < .05$ level, and analysis was completed using GraphPad InStat Version 3.10.

## RESULTS

Over the study period, 966 TOS operations were performed; of these, 401 were for venous TOS, and 33 patients were identified with subacute or chronic preoperative SCV occlusion verified by venography. During the same study time frame, four patients were referred for asymptomatic subacute or chronic occlusion of the SCV. These patients underwent angiography confirming SCV occlusion with ample collateralization. As they were asymptomatic, they did not undergo FRR. A total of 33 patients were identified with occluded SCVs, as defined by preoperative venography, who subsequently underwent surgical thoracic outlet decompression. These 33 patients comprise our study group. Ages ranged from 17 to 59 years, and the median age was 29. The cohort was 73% men and 27% women. The right side was affected in 79% of patients (Table I). Eighteen patients (55%) had prior attempted catheter-directed thrombolysis with tissue plasminogen activator. No patients had preoperative mechanical thrombectomy or venoplasty. No patients presented with preoperative limb threat or phlegmasia. There were no patients who underwent a hybrid approach with FRR and concurrent venography during the study period.

The median time between the onset of deep vein thrombosis and undergoing FRR was 78 days. There were no significant postoperative complications—no injuries to the brachial plexus, phrenic nerve, and long thoracic nerve, and no vascular injuries. The average operative blood loss was 25.9 ± 2.0 cc. The average hospital length of stay was 2.1 ± 1.2 days. The median time between FRR and postoperative venogram was 18 days.

SCV patency was restored in 21 of the 33 patients (64%) on final postoperative venogram. The median time among patients who achieved venous patency after FRR was 71 days as compared with 106 days for those who remained occluded after FRR. Of the patent venous subgroup, 19 patients required balloon angioplasty, 1 patient did not require an endovascular intervention, and 1 patient underwent AngioJet (Boston Scientific) suction thrombectomy. There was no statistically significant difference in the median age of patients who achieved SCV patency after FRR as compared with patients with an occluded SCV after FRR ($P > .05$). On final postoperative venogram, 12 patients (36%) remained occluded despite attempts at percutaneous recanalization and angioplasty (Table I).

Standardized and clinical severity outcome measurements indicated improvement after surgical decompression (Table II). Preoperative standardized measures indicated a relatively mild degree of pain and moderate disability of the group overall (Fig 1). The average preoperative SPS was 1.69 and the preoperative QDS was 27.3. The average duration of follow-up was 5.7 ± 9.1 months for all patients. There was comparative improvement in the average final SPS, 0.25 ± 0.68, and the final postoperative QDS, 10.19 ± 11.81, although differences were not statistically different from original scores ($P > .05$).

**Table II.** Outcome measures (Somatic Pain Scale [*SPS*], QuickDASH score [*QDS*], and Derkash score [*DKS*]) are presented for all patients (All), patients whose subclavian vein (SCV) was patent at last postoperative follow-up (Patent), and patients whose SCV was occluded at last postoperative follow-up (Occluded)

| | All | Patent | Occluded | *P* value |
|---|---|---|---|---|
| SPS | (n = 33) | (n = 21) | (n = 12) | |
| SPS preoperative | 1.69 | 2.18 | 0.60 | n.s. |
| SPS preoperative maximum | 9.0 | 9.0 | 1.0 | |
| SPS preoperative minimum | 0.0 | 0.0 | 0.0 | |
| Standard deviation | 2.55 | 2.96 | 0.55 | |
| SPS postoperative | 0.25 | 0.18 | 0.40 | n.s. |
| SPS postoperative maximum | 2.0 | 2.0 | 2.0 | |
| SPS postoperative minimum | 0.0 | 0.0 | 0.0 | |
| Standard deviation | 0.68 | 0.60 | 0.89 | |
| SPS Delta (pre − post) | 2.0 | 1.43 | 0.20 | n.s. |
| QDS | | | | |
| QDS preoperative | 27.63 | 34.23 | 20.37 | n.s. |
| QDS preoperative maximum | 70.5 | 70.5 | 52.3 | |
| QDS preoperative minimum | 0.0 | 0.0 | 0.0 | |
| Standard deviation | 21.13 | 22.84 | 17.34 | |
| QDS postoperative | 10.19 | 11.22 | 9.06 | n.s. |
| QDS postoperative maximum | 40.9 | 36.4 | 40.9 | |
| QDS postoperative minimum | 0.0 | 0.0 | 0.0 | |
| Standard deviation | 11.81 | 12.5 | 11.56 | |
| QDS Delta (pre − post) | 17.4 | 23 | 11.3 | n.s. |
| DKS—post FRR | | | | |
| No symptoms (class 4) | 57.6% | 52.4% | 66.7% | n.s. |
| Mild (class 3) | 42.4% | 47.6% | 33.3% | n.s. |
| Moderate (class 2) | 0% | 0% | 0% | n.s. |
| Disabling (class 1) | 0% | 0% | 0% | n.s. |

*FRR*, First rib resection; *n.s.*, not statistically significant, $P > .05$, comparison between Patent and Occluded cohorts.

In the subgroup of patients with patent SCV on final venogram (n = 21), the mean SPS was 2.2 ± 3.0 preoperatively and 0.2 ± 0.6 postoperatively ($P > .5$), and the mean QDS was 34.2 ± 22.8 preoperatively and 11.2 ± 12.5 postoperatively ($P > .05$) (Fig 2). The SPS and QDS measurements indicated improvement, but there was no statistically significant difference between groups when compared before and after FRR. In the subgroup of patients who were occluded on final venogram (n = 12), the mean QDS was 20.4 ± 17.3 preoperatively and 9.1 ± 11.6 postoperatively ($P > .05$), whereas the mean SPS was 0.6 ± 0.5 preoperatively and 0.4 ± 0.9 postoperatively ($P > .05$). There was no significant difference of final SPS and QDS between the patent and occluded subjects (Table II).

All DKS indicated either no residual symptoms (class 4, 58%) or mild residual symptoms (class 3, 42%). The DKS in subjects with patent SCV was excellent (class 4) in 52% and good (class 3) in 48% as compared with excellent (class 4) in 67% and mild (class 3) in 33% of patients with occluded SCV (Table II). All patients returned to work after FRR.

Subset analysis to assess the frequency of neurogenic symptoms (numbness, tingling, and weakness) in the two final cohorts failed to explain the observed reduction in symptom severity. The incidence of preoperative arm paresthesia and weakness in the overall group was 27.3%. Of the group who achieved patency after FRR and recanalization, 23.8% experienced preoperative symptoms. Of the group who remained occluded, the incidence of symptoms was 33.3%. The differences between these groups were not statistically significant ($P > .05$).

## DISCUSSION

Our study showed that 63% of patients with PSS and occluded SCV will recover SCV patency as demonstrated by catheter-based venography after FRR and percutaneous recanalization; however, approximately 36% will remain occluded. Standardized clinical metrics demonstrate comparative improvement in the average severity of symptoms after surgical decompression. Surprisingly, the reduction in symptom severity appears to apply to both patients who recovered SCV patency and those who did not. Our report is unique in identifying symptom improvement as recorded by standardized measures, among a group of patients whose SCV remained occluded after FRR and attempted recanalization. Although we observed comparative symptom improvement, we did not identify a statistically significant difference between groups by final SCV patency. This may be explained by the relative moderate symptoms at presentation, small sample size secondary to the rarity of PSS, and inadequate power to demonstrate between-group differences.

Several authors[10-13] have noted restoration of patency and reduction of symptom severity after FRR in occluded SCV; however, analysis of outcomes in those whose SCV remained occluded has not been featured. Subset analysis to assess the frequency of neurogenic symptoms in the two final cohorts failed to explain this observation: the incidence of preoperative arm paresthesia and weakness was comparable in both groups. Thus relief of neurogenic compression would not seem to account for these findings. Another explanation for symptoms relief may be improved collateralization. The relief of

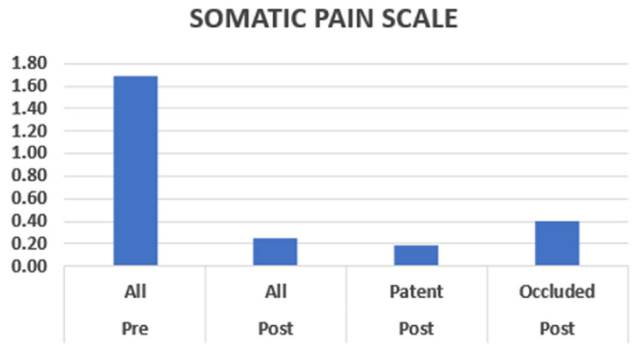


**Fig 1.** Somatic pain scores are presented as mean values for all patients before surgery (All Pre), all patients at final postoperative evaluation (All Post), patients whose subclavian vein (SCV) was patent at last postoperative follow-up (Patent Post), and patients whose SCV was occluded at last postoperative follow-up (Occluded Post). No significant difference comparing All Pre to All Post cohorts ($P > .05$). No significant difference comparing Patent Post to Occluded Post cohorts ($P > .05$).

extrinsic compression with FRR may permit more efficient flow across collaterals and improved development of subsequent collaterals. This may be a mechanism as seen in McCleery syndrome where the alleviation of extrinsic compression allows improved venous return.[14] Other explanations for symptom relief may include the placebo effect or sampling error due to a small study cohort.

The merit of surgical decompression for patients with SCV occlusion due to PSS has been questioned, and the authors have specifically excluded this group of patients from surgical consideration.[15,16] Given the uncertainty of restoring SCV patency, some may question the decision of undertaking thoracic outlet decompression given the attendant risks inherent to the operation. Ultimately, the rationale resides in the clinical severity and the impact of SCV occlusion on the patient's quality of life. Our patients were symptomatic and demonstrated improvement in their degree of clinical impairment. Asymptomatic patients would not be considered candidates as operative risks would outweigh any anticipated benefits of the operation.

The risk of complications from FRR for decompression of PSS has been reported to be between 0 and 23%.[17,18] In our series, there were no pulmonary, hemorrhagic, or neurologic complications. This is similar to and consistent with other publications.[7,19-21] The degree of symptomatology should inform the decision to proceed with surgery. QDS have been used as a metric of symptom severity. In our study, the average preoperative QDS was 27, indicating a moderate degree of symptomatology and impairment. Similar clinical scores have been reported by Freischlag and Lee.[22,23] Although we did not find a statistically significant difference in clinical scores before and after FRR, there was a comparative improvement that has not been described before. The lack of the statistical difference between groups may be explained by the moderate degree of symptoms we identified on preoperative QDS as well as the small sample size and rarity of PSS.

The decision to reconstruct the SCV with open surgical bypass or open venoplasty, as reported by Molina and Thompson,[13,20] remains an area of investigation. The severity of symptoms and degree of disability would be significant factors in this decision. In our experience, these cases did not arise during the study period, and therefore no open venous reconstruction was performed. We did not identify variables that predict who will achieve final SCV patency. Preoperative wire crossing may intuitively indicate that an occluded SCV has a higher probability of re-establishing patency after FRR; however, we identified only one patient with preoperative wire crossing. Although this single patient also achieved SCV patency after FRR, we do not consider preoperative wire crossing a reliable indicator of future SCV patency. Despite no reconstruction of chronically occluded SCVs, our patients did well.

Whereas the observed reduction of symptom severity as recorded in SPS and QDS did not achieve statistical significance, the observed reduction in average scores was unanticipated as it occurred in both patients who achieved patent SCV and those who did not. To clearly establish the benefit of FRR for subacute or chronic SCV occlusion would require a comparator cohort of patients with subacute or chronic SCV occlusion who do not undergo FRR. We do not have access to a comparator cohort, and clearly there is a selection bias as asymptomatic patients would not likely present for surgical intervention. However, the reduction of symptoms in the subgroup of patients who did not recover SCV patency remains an unexpected novel finding.

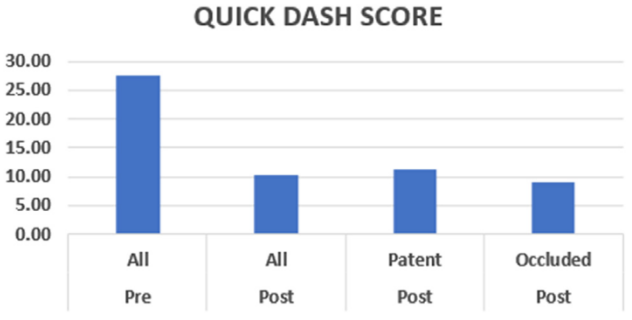


**Fig 2.** Quick Disability Arm, Shoulder, Hand (*QuickDASH*) scores are presented as mean values for all patients before surgery (All Pre), all patients at final postoperative evaluation (All Post), patients whose subclavian vein (SCV) was patent at last postoperative follow-up (Patent Post), and patients whose SCV was occluded at last postoperative follow-up (Occluded Post). No significant difference comparing All Pre to All Post cohorts ($P > .05$). No significant difference comparing Patent Post to Occluded Post cohorts ($P > .05$).

There are several limitations to our study. The small number of subjects limits the conclusions in several ways. Objective measurements of arm congestion such as arm girth or patient-reported complaints (ie, pain and edema) were not available for standardized retrospective abstraction; however, we did use validated patient questionnaires (SDS, QDS, and DKS) to assess changes in symptoms after FRR. The small number and retrospective nature of the study weaken the strength of statistical analysis. There is a clear selection bias as asymptomatic patients would not likely present for surgical intervention. The trend toward the reduction in symptom severity did not achieve statistical significance in part because of the small number of subjects. Moreover, our study is subject to sampling error as a small sample would allow each individual participant to exert greater weight on the measured outcome.

## CONCLUSIONS

Surgical decompression of the thoracic outlet will allow restoration of SCV patency in approximately 63% of patients. Surgical decompression of the thoracic outlet should be considered in patients with subacute and chronic SCV occlusion presenting with clinical disability as they may derive improvement in pain and disability.

## AUTHOR CONTRIBUTIONS

Conception and design: MC, HG
Analysis and interpretation: MC, HG, JR, JU
Data collection: MC, TC, HG
Writing the article: MC, HG, JU
Critical revision of the article: MC, TC, HG, JR, JU
Final approval of the article: MC, TC, HG, JR, JU
Statistical analysis: MC, HG, JU
Obtained funding: Not applicable
Overall responsibility: HG

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