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Original Research

Spasticity Management in Persons with Disorders of Consciousness

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Abstract

Introduction: Spasticity is one of the most frequent neurological impairments affecting persons with disorders of consciousness (DoC). If left untreated, it can mask signs of consciousness by inhibiting one's ability to interact with the environment. The lack of information about spasticity specific to patients with DoC may result in insufficient or even inappropriate treatment.
Objective: To report spasticity characteristics and management in a large dedicated DoC rehabilitation program.
Design: Retrospective chart review.
Setting: An inpatient rehabilitation hospital.
Participants: Patients admitted to the DoC rehabilitation program from 1 January 2014 to 31 October 2018.
Main Outcome Measurements: Spasticity characteristics; impact of interventions on spasticity as well as other clinical measures.
Results: A total of 146 patients were included, of whom 95.2% were affected by spasticity; 52.7% had spasticity affecting all four limbs. The most commonly affected muscle groups were shoulder internal rotators (72.6%) in the upper extremity and ankle plantar flexors (59.8%) in the lower extremity. The more commonly affected muscle groups were also more spastic (R = 0.993 and 0.989 in the upper and lower extremity, respectively; $P < .01$). Atypical posture patterns were also commonly observed, making positioning difficult. Chemoneurolytic injections (botulinum toxin and/or phenol) were performed in over 69.9% patients, and 26.7% had intrathecal baclofen (ITB) pump placement. All patients received individualized physical modalities and therapies. With focal managements, systemic spasmolytic medications, including enteral baclofen, were reduced by at least 50.0%, which appeared to be associated with improvements in the level of consciousness.
Conclusions: Almost all DoC patients were affected by spasticity, often to a moderate or severe degree. Extensive use of focal spasticity interventions allowed for weaning of systemic spasmolytic medications, which seemed to result in improvements in the level of consciousness.

Introduction

Persons with severe brain injuries may experience disorders of consciousness (DoC) as a result of extensive injury to the brain.[1] Affected persons have no or extremely limited awareness and significant physical disability. Spasticity is one of the most frequently reported medical comorbidities with a prevalence of 59%–89%.[2-4] Spasticity in this unique population is often challenging to treat.[5] Early- and goal-directed spasticity management is vital to prevent or ameliorate pain, improve hygiene, and minimize the loss of joint range of motion (ROM).[6] Successful management of spasticity may also aid in the evaluation and detection of consciousness.

Current spasticity treatment options include physical modalities,[7,8] focal injections (chemodenervation with botulinum neurotoxin [BoNT] or phenol neurolysis),[9-11] systemic medications (mainly baclofen, tizanidine, dantrolene),[12] and invasive surgical approaches (intrathecal baclofen [ITB], selective dorsal rhizotomy [SDR], and thalamic stimulation).[5,6,13] Of these, only bracing, BoNT, and systemic and intrathecal baclofen have been reported for spasticity management in this population.[5,6]

Severe and diffuse spasticity in persons with DoC may lead to the use of high doses of systemic spasmolytic

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medications. However, the sedative and cognitive impairing side effects of systemic spasmolytic medications may diminish arousal and the level of consciousness. Currently, no specific recommendations or guidelines exist for spasticity management for this population. Thus, affected patients may receive insufficient or even improper management of their spasticity.[2,14]

Prompted by the marked paucity of evidence for spasticity management specific to persons with DoC, this study was intended to summarize the clinical experience with spasticity management in a large cohort of persons admitted to a dedicated DoC rehabilitation program.

Methods

Study Cohort

We retrospectively reviewed patients who were admitted to the DoC Rehabilitation Program from 1 January 2014, to 31 October 2018. Within the first week of admission, the clinical determination of the patient's level of consciousness was made by a dedicated group of professionals with extensive experience with DoC; this was also performed prior to final discharge. Standard demographic information and clinically relevant parameters were extracted from the electronic medical record for review. The study was approved by the local institutional review board.

Spasticity Characteristics

Modified Ashworth Scale (MAS) scores were collected from the initial therapists' evaluations produced within 24 hours of the first admission. Each evaluation included an assessment of 18 muscle groups in the upper extremity and 14 muscle groups in the lower extremity. The muscle tone was graded as MAS "0," "1," "1+," "2," "3," "4," or "hypotonic," or "unable to assess,", or not recorded. Each MAS grade was assigned a numeric score (0, 1, 2, 3, 4, 5, respectively) for further analysis. Inability to perform muscle tone assessment occurred for various reasons, including but not limited to contracture, unable to properly position limbs, body habitus, fracture with cast or external pins, posturing/storming, pain, and a significant increase in heart rate.

Prevalence of Spasticity

A patient was considered affected by spasticity if identified as having an MAS grade >= 1 in any muscle group. The prevalence was calculated by the percentage of the "patients affected by spasticity" among the full cohort. Similarly, the prevalence for those patients having an MAS grade >= 2 or >=3 in any muscle group was calculated, respectively, to demonstrate relative severity of spasticity.

Muscle Involvement of Spasticity

An individual muscle group was considered affected by spasticity with an MAS grade >= 1. Involvement of an individual muscle group was calculated by the percentage of the "patients with spasticity of the muscle group" among the full cohort (excluding those patients whose tone was unable to be assessed for the reasons mentioned previously).

Severity of Spasticity

A designation of severe spasticity was given to muscle groups with an MAS grade of 3 or 4. Similarly, muscle involvement of severe spasticity was calculated by the percentage of the "patients with severe spasticity of a muscle group" among the full cohort (excluding those patients whose tone was unable to be assessed for the reasons mentioned previously).

Distribution and Pattern of Spasticity

The involvement of spasticity in each limb was identified by any muscle group in the limb having documented MAS >= 1. This was then summarized and formulated into the descriptive distribution of spasticity of the limbs, including quadri-, tri-, di-, hemi-, mono-spasticity, or normotonic or hypotonic. The patterns of the resting spastic limbs' position in bed among patients with quadri-spasticity were reviewed and summarized.

Spasticity Management

Changes in the utilization of enteral spasmolytic medications, including baclofen, tizanidine, dantrolene, and benzodiazepines, was analyzed based on medication lists in the first admission and the last discharge notes for each patient. A consistent approach within the rehabilitation team was to minimize use of systemic spasmolytic medications.

The injection targets for patients receiving chemodenervation with BoNT or phenol neurolysis were collected and summarized. ITB parameters, including ITB pump status on admission, trialing and results, and subsequent ITB pump placement, were collected. Surgical interventions, including muscle release or tendon lengthening surgeries, were analyzed.

Data Analysis

Data were analyzed using SPSS 20.0 (IBM Corp., Armonk, NY). The correlation between muscle involvement and the mean MAS score among different muscle groups was examined using Pearson's correlation as both data followed the normal distribution. Chi-square test, or Fisher's exact test when there is N < 5 in the cell, was used to analyze the difference in the proportion of patients' conscious states on admission and at discharge based on management factors. Statistical significance was set at $P < .05$.

Data Availability

Anonymized data can be made available on reasonable request from a qualified investigator.

Results

Demographics

A total of 146 patients were included in the cohort; their relevant demographic and clinical parameters are presented in Table 1. The majority of patients were young (in their 30s), male (74%), and sustained a traumatic brain injury (TBI, 60%). Approximately half of the patients were admitted within 1 month after injury. Clinical diagnoses of the unresponsive wakefulness syndrome/vegetative state (UWS/VS) and the minimally conscious state (MCS) were similar in proportion. Nine patients (6%) were determined as "emerged from DoC" after close observation and meticulous evaluation during the first week of admission. It was difficult to determine whether the patients had already emerged at the time of admission or had emerged after admission, sometime during the first week. Therefore, these patients were not excluded because of the similarity of their clinical presentation to the other patients. Around 30% of patients eventually underwent multiple phases of inpatient rehabilitation, either in the DoC or, if emerged, the brain injury rehabilitation programs.

Table 1
Demographics of the 146 cases reviewed

Age (y, mean ± SD)	36 ± 15
Gender (N, %)	
Female	38 (26.0%)
Male	108 (74.0%)
Etiology (N, %)	
TBI	87 (59.6%)
ABI	42 (28.8%)
Stroke	11 (7.5%)
Mixed	6 (4.1%)
Months since injury (N, %)	Mode: 1
	Median: 2
	Mean: 8
<=1	71 (48.6%)
=2	25 (17.1%)
=3	11 (7.5%)
=4	3 (2.1%)
=5	2 (1.4%)
>=6	34 (23.3%)
Diagnosis on admission (N, %)	
UWS/VS	63 (43.1%)
MCS	74 (50.7%)
Emerged	9 (6.2%)
Craniectomy/cranioplasty (N, %)	59 (40.4%)
Number of admissions* (N, %)	
1	100 (68.5%)
2	33 (22.6%)
3	8 (5.5%)
>=4	5 (3.4%)
ITB pump prior to first admission (N, %)	5 (3.4%)

TBI = traumatic brain injury; ABI = anoxic brain injury; VS = vegetative state; UWS = unresponsive wakefulness syndrome; MCS = minimally conscious state; ITB = intrathecal baclofen.
*Determined as planned admission and discharge encounters; therefore, acute unplanned transfer and subsequent readmission (eg, for medical emergencies) did not count as an independent admission.

Spasticity Characteristics

Prevalence, Distribution and Patterns of Spasticity

Spasticity was present in at least 139 of 146 patients (95.2%) on admission; 80.8% of patients (118 of 146 patients) had MAS >= 2 in at least one muscle group, and 56.8% of patients (83 of 146 patients) had MAS >= 3 in at least one muscle group. Over half (52.7%) of the affected patients had spasticity affecting all four limbs. Quadri-spasticity (N = 77; 52.7%), tri-spasticity (N = 23; 15.7%), di-spasticity (N = 27; 18.5%), and mono-spasticity (N = 12; 8.2%) were all observed. Six patients were recorded as "hypotonic" and one patient was recorded as "normal" in four limbs. No hemi-spasticity was observed. Among the patients affected by quadri-spasticity, atypical postures, including decorticate and decerebrate postures, were observed and are summarized in Figure 1.

Muscle Involvement of Spasticity

In general, spasticity was more prevalent in the upper extremities than in the lower (Figure 2) at the time of admission. The most commonly affected muscle groups in the upper extremities included shoulder internal rotators (72.6%), wrist flexors (68.0%), elbow flexors (66.3%), finger flexors (60.2%), forearm pronators (59.7%), shoulder extensors (58.3%), and shoulder adductors (56.9%). The most commonly affected groups in the lower extremities included ankle plantar flexors (59.8%), hip adductors (59.3%), knee flexors (48.3%) and extensors (35.8%), and hip extensors (37.0%). See further details in Table S1.

Severity of Spasticity

Severe spasticity (MAS 3 and 4) was most pronounced in the shoulder internal rotators (28.7%) and shoulder adductors (20.5%) in the upper extremities and the ankle plantar flexors (25.7%) and hip adductors (20.2%) in the lower extremities (Figure 2) at time of admission. The more commonly affected muscles were also more spastic. The mean MAS scores of the muscle groups were positively correlated with their spasticity involvement at the time of admission ($R = 0.993$ in the upper extremity, $R = 0.989$ in the lower extremity, $P < .01$ for both; Figure 3).

Spasticity Management

In our cohort, all patients received timely, individualized, appropriate physical modalities including passive ROM, stretching, splinting, casting, bracing, standing on

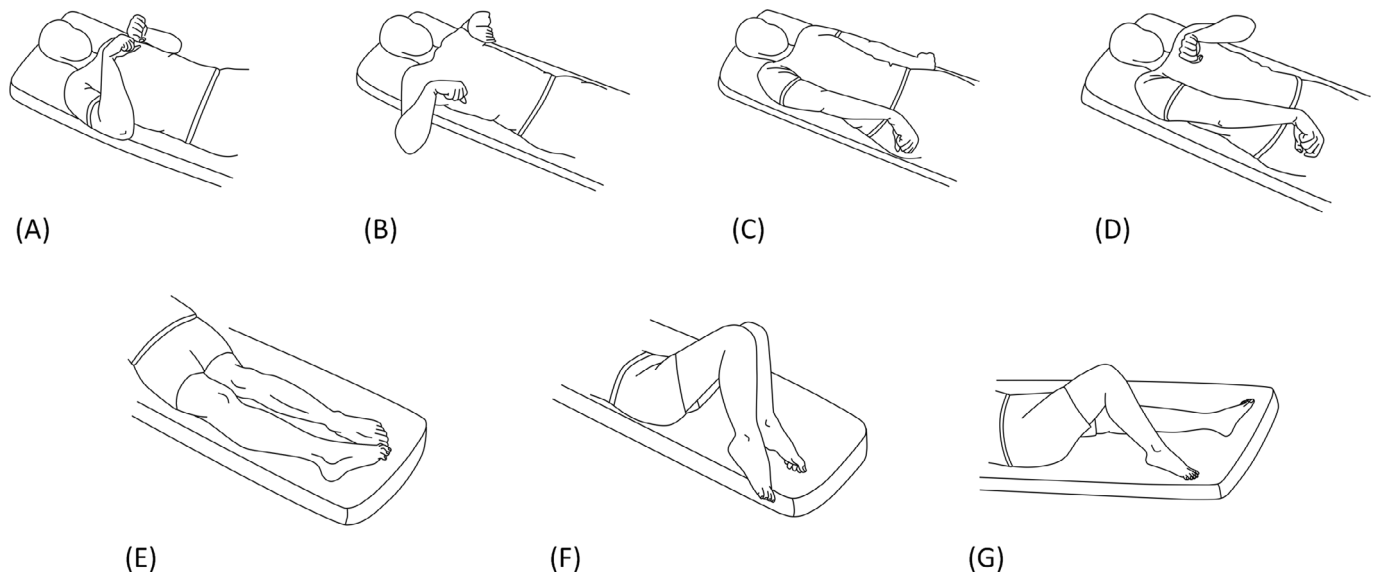
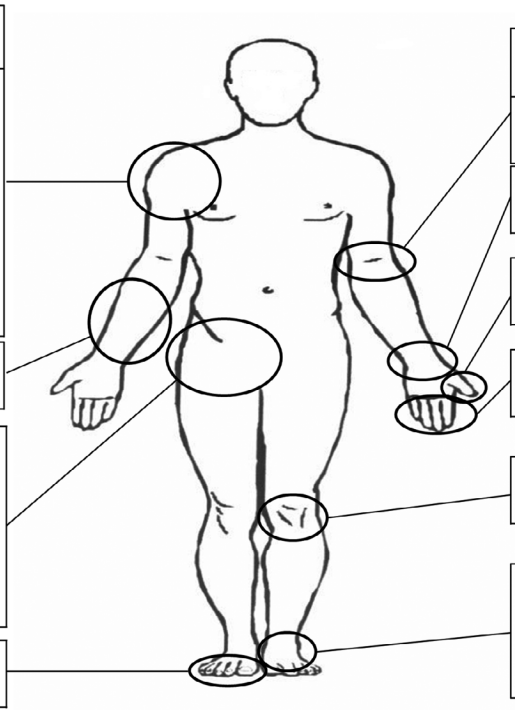


Figure 1. Patterns of spasticity in patients affected by quadri-spasticity. Typical postures included decorticate pattern (A and E) and decerebrate pattern (C and E). Atypical postures included, but not limited to, postures with shoulder abduction (B), a mixed flexion and extension pattern on both upper (D) and lower (G) extremities, abnormal posture with bilateral knee flexion with/without "windswept" to either side (F), a few cases with wrist extension, and very rarely, abnormal posture with ankle dorsiflexion. Head and neck postures were not summarized here.

	Prevalence [%,Mean(SD)]	Severe / MAS 3&4 [%,Mean(SD)]	Mean MAS [Mean(SD)]
SF	19.1 (3.8)	4.7 (1.2)	0.46 (0.06)
SE	**58.3 (5.7)**	**18.9 (1.2)**	**1.65 (0.05)**
SAbd	17.3 (1.1)	1.3 (0.1)	0.37 (0.02)
SAdd	**56.9 (0.9)**	**20.5 (2.5)**	**1.60 (0.05)**
SHzAbd	13.4 (2.5)	0.0 (0.0)	0.22 (0.02)
SHzAdd	20.8 (8.8)	2.1 (0.0)	0.49 (0.22)
SInRo	**72.6 (0.1)**	**28.7 (1.8)**	**2.14 (0.07)**
SExRo	12.5 (1.2)	2.1 (1.1)	0.27 (0.01)
FS	22.6 (2.2)	3.0 (0.6)	0.49 (0.01)
FP	**59.7 (4.6)**	**17.9 (4.4)**	**1.57 (0.17)**
HF	28.0 (0.4)	4.2 (0.0)	0.67 (0.01)
HE	**37.0 (1.3)**	**11.0 (0.4)**	**1.02 (0.02)**
HAbd	8.2 (3.1)	0.4 (0.6)	0.21 (0.07)
HAdd	**59.3 (2.3)**	**20.2 (3.5)**	**1.69 (0.14)**
HExRo	16.9 (2.6)	3.6 (1.3)	0.44 (0.07)
HInRo	**29.7 (4.4)**	7.0 (0.1)	**0.74 (0.07)**
TF	15.9 (1.1)	5.3 (1.1)	0.45 (0.07)
TE	10.6 (3.2)	3.2 (0.6)	0.31 (0.06)



	Prevalence [%,Mean(SD)]	Severe / MAS 3&4 [%,Mean(SD)]	Mean MAS [Mean(SD)]
EF	**66.3 (2.1)**	**19.2 (0.8)**	**1.77 (0.08)**
EE	**38.7 (0.6)**	8.1 (0.9)	**0.97 (0.08)**
WF	**68.0 (1.1)**	**18.0 (0.8)**	**1.73 (0.11)**
WE	22.4 (2.0)	8.1 (0.9)	0.63 (0.04)
ThAdd	**30.7 (0.4)**	6.7 (2.3)	**0.67 (0.14)**
ThF	25.6 (5.3)	3.9 (1.7)	0.55 (0.02)
FF	**60.2 (1.8)**	**16.3 (1.0)**	**1.52 (0.03)**
FE	11.5 (3.7)	1.3 (0.0)	0.20 (0.06)
KF	**48.3 (5.8)**	8.6 (0.4)	**1.24 (0.15)**
KE	**35.8 (1.9)**	**13.4 (1.6)**	**1.04 (0.05)**
APF	**59.8 (3.4)**	**25.7 (2.7)**	**1.87 (0.10)**
ADF	10.1 (0.5)	5.3 (1.2)	0.33 (0.03)
AInvt	**29.9 (3.3)**	8.7 (0.5)	**0.83 (0.07)**
AEvt	13.4 (0.6)	4.3 (0.0)	0.40 (0.03)

Figure 2. The results of muscle involvement, severity, and respective mean MAS scores [SD] in the upper and lower extremities. MAS = Modified Ashworth Scale; SF = shoulder flexors; SE = shoulder extensors; SAbd = shoulder abductors; SAdd = shoulder adductors; SHzAbd = shoulder horizontal abductors; SHzAdd = shoulder horizontal adductors; SInRo = shoulder internal rotators; SExRo = shoulder external rotators; EF = elbow flexors; EE = elbow extensors; FS = forearm supinators; FP = forearm pronators; WF = wrist flexors; WE = wrist extensors; FF = finger flexors; FE = finger extensors; ThAdd = thumb adductors; ThF = thumb flexors; HF = hip flexors; HE = hip extensors; HAbd = hip abductors; HAdd = hip adductors; HExRo = hip external rotators; HinRo = hip internal rotators; KF = knee flexors; KE = knee extensors; APF = ankle plantar flexors; ADF = ankle dorsiflexors; AInvt = ankle invertors; AEvt = ankle evertors; TF = toe flexors; TE = toe extensors.

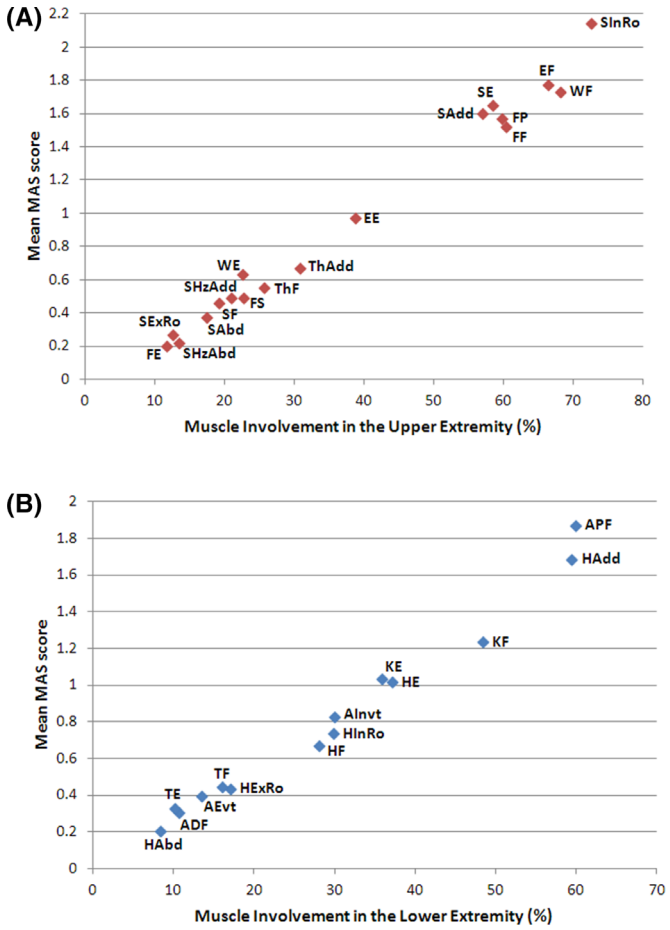


Figure 3. (A) The relationship between the individual muscle group and its respective mean MAS score in the upper extremity; (B) The relationship between the individual muscle group and its respective mean MAS score in the lower extremity. MAS = Modified Ashworth Scale; SF = shoulder flexors; SE = shoulder extensors; SAbd = shoulder abductors; SAdd = shoulder adductors; SHzAbd = shoulder horizontal abductors; SHzAdd = shoulder horizontal adductors; SInRo = shoulder internal rotators; SExRo = shoulder external rotators; EF = elbow flexors; EE = elbow extensors; FS = forearm supinators; FP = forearm pronators; WF = wrist flexors; WE = wrist extensors; FF = finger flexors; FE = finger extensors; ThAdd = thumb adductors; ThF = thumb flexors; HF = hip flexors; HE = hip extensors; HAbd = hip abductors; HAdd = hip adductors; HExRo = hip external rotators; HinRo = hip internal rotators; KF = knee flexors; KE = knee extensors; APF = ankle plantar flexors; ADF = ankle dorsiflexors; AInvt = ankle invertors; AEvt = ankle evertors; TF = toe flexors; TE = toe extensors.

the tilt table or the body-weight reduction system, as appropriate.

The use of systemic spasmolytic medications is presented in Figure 4A; the most commonly used medication was baclofen. All benzodiazepines were prescribed for medical conditions other than spasticity (such as seizure, sympathetic storming, catatonia, or myoclonus). The discontinuation rates for these systemic medications across the rehabilitation course were 79.0% (30/38) for baclofen, 100.0% (2/2) for tizanidine, 60.0% (3/5) for dantrolene, and 50.0% (5/10) for benzodiazepines. Discontinuation of these medications appeared to correlate with improvement in the level of consciousness, as presented in Figure 4B. Limited by the sample size, Fisher's exact test showed statistical difference in the composition of consciousness only in the group of patients who were weaned off of baclofen, with a higher proportion of emergence (P = .000). Taken together, 119 patients did not take any medications, whereas 27 patients were on at least one of these medications upon discharge. However, the emergence rate at discharge—58.2% (64/110; excluding nine patients who were considered emerged shortly after admission) versus 44.4% (12/27)—was not statistically significant (χ^2 = 1.656, P = .198).

Focal spasticity injections, including chemodenervation with BoNT and phenol neurolysis, were administered to a majority of patients. In our cohort, 59.6% (87/146) received BoNT and 51.4% (75/146) received phenol; 41.1% (60/146) received both injections. Collectively, 69.9% (102/146) received either BoNT or phenol injections, and 30.1% (44/146) did not receive any injection. The upper extremity (95.4%, 83/87) and the neck muscles (58.6%, 51/87) were major targets for BoNT injection, whereas the lower (92.0%, 69/75) and upper (68.0%, 51/75) extremity muscles were major targets for phenol injection. See further details in Figure S1.

Over a third of the patients (52/146) underwent an ITB trial with a 92.3% positive rate (48/52). Eventually, 34 of the 48 responders (70.8%) underwent ITB pump placement. Considerations for not proceeding with pump placement following a successful trial included limited follow-up by specialists, lack of adequate family care, and awaiting the response to focal injections. Collectively, 26.7% (39/146) patients in the cohort had an ITB pump, including five patients who had pump placement prior to the admission (details in Figure S1). It is noted that a patient may receive BoNT or phenol injection prior to ITB trial or pump placement as a bridging treatment if necessary. A significant proportion of patients with or without an ITB pump had improvement in their level of consciousness (Figure 4C). A total of 65.7% (25/38) of patients with ITB pumps at discharge were considered emerged from DoC, compared with 51.5% (51/99) in patients without ITB pumps (χ^2 = 2.265, P = .132; excluding nine patients who were considered emerged shortly after admission).

Surgical interventions were recommended for those with contractures. In the cohort, 12.3% (18/146) patients underwent muscle release/tendon lengthening surgery (details in Figure S1). In this cohort, all treatment options were available and used as appropriate to achieve major goals during their inpatient rehabilitation stay. In fact, most patients received multiple interventions including systemic medications, focal injections, and possibly intrathecal baclofen therapy to optimize spasticity control (an example is shown in Figure 5).

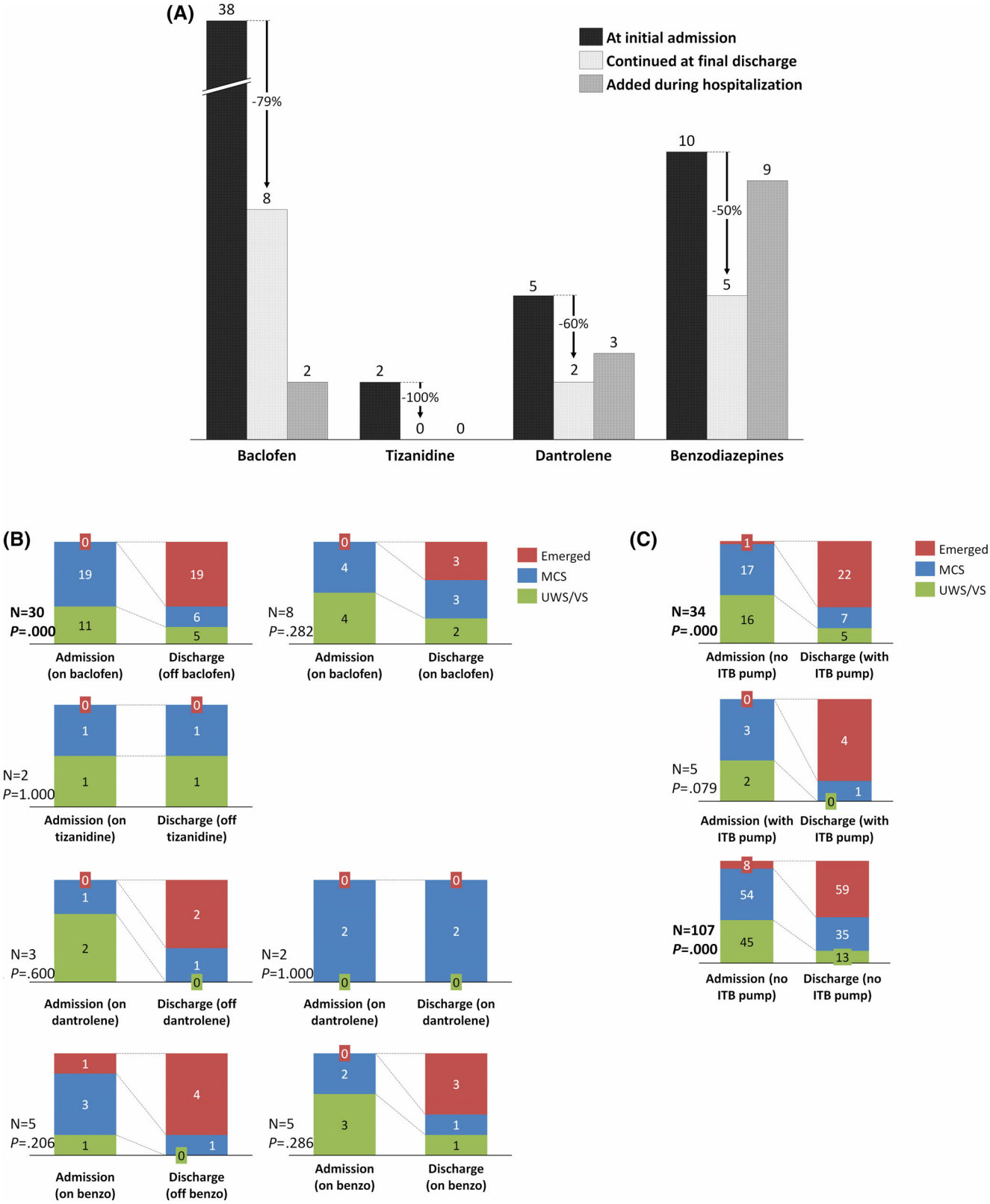


Figure 4. (A) Management of systemic spasmolytic medications during the rehabilitation course; (B) The comparison of conscious states on admission and discharge between patients who were weaned off of spasmolytic medications (left column) and who continued to take the medications (right column); (C) The comparison of conscious states on admission and discharge between patients who had ITB pump (the first two subsections) and had no ITB pump (the third subsection). The numbers on top of the bar and in the box indicate the number of cases. ITB = intrathecal baclofen; MCS = minimally conscious state; UWS = unresponsive wakefulness syndrome; VS = vegetative state.

Figure 5. A representative case, showing the effects of multimodal spasticity management. This was a 25-year-old man who suffered a severe traumatic brain injury after a fall 15 months before the initial admission with a resultant disorder of consciousness and severe spastic quadriplegia. On admission, he was receiving 36 mg tizanidine and 100 mg baclofen daily for spasticity management. He had not received any injections or surgery prior to admission. On the second day of admission, he received phenol injections and casting to his bilateral legs. He subsequently received botulinum neurotoxin injections to his upper extremities and, eventually, intrathecal baclofen (ITB) pump implantation. His enteral spasmolytic medications were weaned off after the pump implantation. After these interventions, the patient had better positioning, easier hygiene care, and better scores on the Coma Recovery Scale-Revised (CRS-R), a standardized measure used to assess consciousness.

Discussion

Although previous studies have reported a high prevalence of spasticity in persons with DoC, there are currently no guidelines for management in this population.[2-4] To our knowledge, this is the first comprehensive report on spasticity features and management strategies in persons with DoC.

Characteristics of Spasticity in Persons with DoC

Of particular note is the widely distributed pattern of spasticity in patients in our cohort. The prevalence of spasticity at admission was 95.2% with varying degrees of severity, even higher than previous reports.[2-4] Spasticity in patients with DoC tends to develop across the midline of the body, frequently affecting two or more limbs, manifested in both antigravity and gravitropic muscles. This variety of presentations may reflect diffuse and profound damage to bilateral descending motor tracts.[15] Although the underlying mechanisms remain unclear, it is possible that spasticity developed secondary to inappropriate positioning and prolonged immobilization, which facilitates biomechanical changes in conjunction with the gradually emerging neuromuscular hyperexcitability due to severe brain injury.[16,17] Unlike other brain injury patients, who either have some spontaneous movements or are able to express discomfort, patients with DoC are entirely dependent on others to recognize the need and then execute appropriately for positioning and turning. These patients are also less likely to receive aggressive ranging and stretching of the limbs. Commonly affected muscles, such as shoulder internal rotators, hip adductors, and ankle plantar flexors, warrant early attention and aggressive interventions, as their spasticity is often more severe.

Spasticity Management in DoC

The important goals of spasticity management for persons with DoC include reducing pain, decreasing burden of care, and liberating latent voluntary movement. In contrast to the centers described in previous reports, our institution used almost all available treatment modalities for the management of spasticity. Physical modalities were used early and frequently as a supplement to other treatments. Focal injections were also widely used. The extensive use of injections and physical modalities allowed our institution to minimize the use of systemic spasmolytic medications, which can adversely affect arousal and cognition.[12] The injections administered consisted of both phenol and BoNT. Phenol neurolysis can effectively manage spasticity in several muscles innervated by the same nerve, which is helpful in managing the widespread severe spasticity in persons with DoC. It takes effect in minutes, and could be repeated in days if necessary, which is ideal for use in the inpatient setting.[10,11] BoNT injections can be used to treat small muscles (eg, the lumbricals) or neck muscles (eg, the sternocleidomastoid muscle), in order to facilitate movement for communication or environmental control. Finally, by utilizing a mechanism of delivery at the microgram level of dosing into the intrathecal space, ITB pumps can be efficacious in managing spasticity in the lower extremities with a potential or additional effect on the trunk and upper extremities. As a result of

the use of modalities, focal injections, and ITB pumps, the dose of systemic medications such as enteral baclofen could be reduced. The combined use of these modalities can help to maximize management of severe and diffuse spasticity in persons with DoC while minimizing cognitive side effects, as shown in Figure 5. The disadvantages of these interventions include high technical/mechanical requirements, high costs, and sparse availability. Persons with ITB pumps often require a dedicated ITB pump program with the logistical mechanisms in place for professional support, maintenance, and emergency troubleshooting.

It is noted that some reports have suggested that ITB therapy may promote the emergence of consciousness.[18] This phenomenon did not seem to be present in our cohort. As shown in Figure 4C, both groups with or with ITB pump placement showed significant improvement in consciousness. In contrast, minimizing enteral baclofen appeared to be associated with improved consciousness (Figure 4B). However, this association is inconclusive owing to existing confounders (eg, use of neurostimulants, neurosurgical interventions, weaning of other sedating medications, etc).

Study Limitations

There are several weaknesses related to the retrospective study design utilized in this report. Data incompleteness may lead to overestimated or underestimated results. Also, the study was able to provide only a cross-sectional view of spasticity development as patients entered into rehabilitation program at varying times post-injury (although most were admitted at an early stage, shortly after acute management). This may result in an artificially low level of spasticity severity, despite the already alarming severity of spasticity. Further stratification may help reveal spasticity features in different stages after injury; however, this will require a larger sample size and uniformed baseline with or without treatments. The study was not designed to evaluate any treatment effects. Interpretation of the results, especially those related to consciousness outcomes, should be with extreme caution. Currently, no objective criteria exist for assessing the efficacy of spasticity management in the DoC population. Commonly used clinical scales, such as the MAS, may not fully reflect the changes in the neuromuscular abnormality and their clinical significance, the latter potentially leading to decisions that affect the long-term functioning of the patient. From a clinical management perspective, functional parameters or complication prevention goals may be better, such as ROM and positioning, minimization of cognitive limiting medications, avoidance of surgical interventions, reduction in spasticity-related skin issues, and improvement in therapy tolerance. Well-designed prospective studies with larger sample size, stratifications, and better evaluation tools are needed.

Conclusion

Almost all DoC patients were affected by spasticity, often to a moderate or severe degree. Extensive use of focal spasticity interventions allowed for weaning of systemic spasmolytic medications, which seemed to result in improvements in the level of consciousness.

Acknowledgments

We would like to sincerely thank Dr. Guyu Li for his artistic talent and generous assistance in the illustrations in Figure 1. We would like to thank all therapists and physicians at TIRR Memorial Hermann Hospital for their efforts in maintaining the medical records.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

References

1. Eapen BC, Georgekutty J, Subbarao B, Bavishi S, Cifu DX. Disorders of consciousness. *Phys Med Rehabil Clin N Am*. 2017;28:245-258.
2. Thibaut FA, Chatelle C, Wannez S, et al. Spasticity in disorders of consciousness: a behavioral study. *Eur J Phys Rehabil Med*. 2015; 51:389-397.
3. Nakase-Richardson R, McNamee S, Howe LL, et al. Descriptive characteristics and rehabilitation outcomes in active duty military personnel and veterans with disorders of consciousness with combat- and noncombat-related brain injury. *Arch Phys Med Rehabil*. 2013; 94:1861-1869.
4. Ganesh S, Guernon A, Chalcraft L, Harton B, Smith B, Louise-Bender Pape T. Medical comorbidities in disorders of consciousness patients and their association with functional outcomes. *Arch Phys Med Rehabil*. 2013;94:1899-1907.
5. Martens G, Laureys S, Thibaut A. Spasticity Management in Disorders of consciousness. *Brain Sci*. 2017;7:162.
6. Martens G, Foidart-Dessalle M, Laureys S, et al. Chapter 7: how does spasticity affect patients with disorders of consciousness? In: Schnakers C, Laureys S, eds. *Coma and Disorders of Consciousness*. 2nd ed. New York, NY: Springer; 2017:119-135.
7. Harvey LA, Katalinic OM, Herbert RD, et al. Stretch for the treatment and prevention of contractures. *Cochrane Database Syst Rev*. 2017;1:D7455.
8. Lannin NA, Novak I, Cusick A. A systematic review of upper extremity casting for children and adults with central nervous system motor disorders. *Clin Rehabil*. 2007;21:963-976.
9. Yablon SA, Agana BT, Ivanhoe CB, Boake C. Botulinum toxin in severe upper extremity spasticity among patients with traumatic brain injury: an open-labeled trial. *Neurology*. 1996;47:939-944.
10. Karri J, Mas MF, Francisco GE, Li S. Practice patterns for spasticity management with phenol neurolysis. *J Rehabil Med*. 2017;49: 482-488.
11. Karri J, Zhang B, Li S. Phenol Neurolysis for Management of Focal Spasticity in the distal upper extremity. *PM R*. 2020;12:246-250.
12. Laxe S. Which interventions are useful for managing muscle spasticity in individuals who sustained traumatic brain injury? - a Cochrane review summary with commentary. *NeuroRehabilitation*. 2019;44: 157-159.

13. Becker R, Alberti O, Bauer BL. Continuous intrathecal baclofen infusion in severe spasticity after traumatic or hypoxic brain injury. *J Neurol*. 1997;244:160-166.
14. Thibaut A, Wannez S, Deltombe T, Martens G, Laureys S, Chatelle C. Physical therapy in patients with disorders of consciousness: impact on spasticity and muscle contracture. *NeuroRehabilitation*. 2018; 42:199-205.
15. Li S. Spasticity, motor recovery, and neural plasticity after stroke. *Front Neurol*. 2017;8:120.
16. Baude M, Nielsen JB, Gracies JM. The neurophysiology of deforming spastic paresis: a revised taxonomy. *Ann Phys Rehabil Med*. 2019;62: 426-430.
17. Gracies JM. Pathophysiology of spastic paresis. I: paresis and soft tissue changes. *Muscle Nerve*. 2005;31:535-551.
18. Al-Khodairy AT, Wicky G, Nicolo D, et al. Influence of intrathecal baclofen on the level of consciousness and mental functions after extremely severe traumatic brain injury: brief report. *Brain Inj*. 2015;29:527-532.

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