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Resource Utilization and the Use of Bone Stimulators among Operatively and Nonoperatively Managed Scaphoid Nonunion Patients

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Background: The prevalence of bone stimulator use among nonoperatively and operatively managed scaphoid nonunion patients is unknown. We hypothesize that bone stimulators are a relatively underutilized treatment for scaphoid nonunion patients.
Methods: We used the 2009–2017 Truven Marketscan Research Databases to identify patients with closed scaphoid fractures and performed an analysis of variance test to determine resource utilization and bone stimulator use among these patients.
Results: A total of 36,611 patients with scaphoid fractures were identified: 30,143 were managed nonoperatively and 6468 were managed operatively. Nonunion was diagnosed in 500 (1.66%) nonoperatively and in 1211 (19%) operatively managed patients. Bone stimulators were used in less than 2% of nonoperatively and operatively managed scaphoid nonunion patients.
Conclusion: Lack of trust in the technology and heterogenous (and occasionally burdensome) requirements for insurance approval are barriers to bone stimulator use; however, surgeons should examine how this technology may fit into the treatment algorithm for these difficult cases. *(Plast Reconstr Surg Glob Open 2023; 11:e4782; doi: 10.1097/GOX.0000000000004782; Published online 26 January 2023.)*

INTRODUCTION

The scaphoid is the most fractured wrist bone, comprising 50%–90% of all carpal fractures.[1] The retrograde blood supply of the scaphoid makes it one of the most difficult bones to heal.[2] Treatment is largely predicated on the location of fracture and whether displacement has occurred. Nondisplaced fractures of the waist are most common and often managed successfully with a thumb spica cast, whereas displaced fractures and those in the proximal pole typically require surgical fixation.[3,4] Nonunion is a radiographic diagnosis, typically defined as the lack of bridging bone across a fracture site 6 months after an injury; the rate of scaphoid nonunion varies in the literature from 5% to 12% with some studies citing rates as high as 47%.[5] Because scaphoid nonunion can lead to scaphoid nonunion advanced collapse and subsequent early onset osteoarthritis, increased attention is paid to the acute diagnosis.[6–10]

Early identification of scaphoid fractures, as well as minimizing risk factors for nonunion, results in better patient outcomes at decreased costs. Surgical intervention for scaphoid fractures is variable and depends on the location of the fracture and quality of the remaining bone. Interventions include open/percutaneous reduction and fixation, as well as open reduction and internal fixation (ORIF) with pedicled or free vascularized bone flaps. Despite the advances in surgical techniques, the overall cost to the healthcare system to care for scaphoid fracture patients can be tremendous with frequent imaging, occupational therapy needs, chronic pain medication consumption, and multiple procedures.[11,12]

Bone stimulators induce new bone formation, promote fracture healing, and can ignite healing in patients with

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nonunion.[13] They have been successfully used to augment spinal fusion as well as femur, tibial, and radius fracture healing.[14–16] Despite this, bone stimulator use for scaphoid nonunion remains controversial, and it has yet to be widely accepted. Insurance companies varying and arduous requirements for approval further limit its use.[17] We investigated the use of electrical bone stimulators among nonoperatively and operatively managed scaphoid nonunion patients. We hypothesize that bone stimulators are relatively underutilized in the management of scaphoid nonunion patients.

METHODS

Data Source and Study Cohort

We used the Truven Health Marketscan Commercial and Supplemental Database from 2009 to 2017 to identify patients with closed scaphoid fractures. This database consists of patient-level medical records, reimbursements, and health care expenditures across inpatient and outpatient settings. The health care usage of over 90 million active employees, early retirees, Medicare-eligible retirees, and their dependents are represented by Marketscan each year. This extensive database includes over 30 billion health records representing inpatient and outpatient encounters, making it the most comprehensive employer-based collection of patient data in the United States; it includes health insurance claims from private insurers, Medicare, and Medicaid, and claims from the uninsured.

Takeaways

Question: What is the role of bone stimulators among scaphoid fracture patients?

Findings: Bone stimulators are infrequently used among scaphoid fracture patients with nonunion.

Meaning: Surgeons should consider where bone stimulators can be used to adjunct healing among complicated scaphoid nonunion patients.

For the current study, we identified patients with International Classification of Diseases, Ninth Revision and Tenth Revision diagnosis codes for closed scaphoid fractures or scaphoid nonunion between January 1, 2009, and December 31, 2015. We required patients to be enrolled at least 1 month before the date of their fracture diagnosis to exclude patients with other acute hand/wrist trauma or open scaphoid fracture within this time frame. Additionally, we required 24 consecutive months of enrollment and excluded patients who were younger than 18 or older than 65. We divided the patient cohort into operative and nonoperative groups. Patients in the operative group were identified with specific scaphoid operative procedure CPT codes. Nonoperative patients were identified by CPT code for closed reduction and/or lack of an operative CPT code (Fig. 1). We split each group of patients into nonunion and routine healing subgroups based on ICD 9 or 10 codes. To better characterize the treatment options, operative scaphoid fracture patients

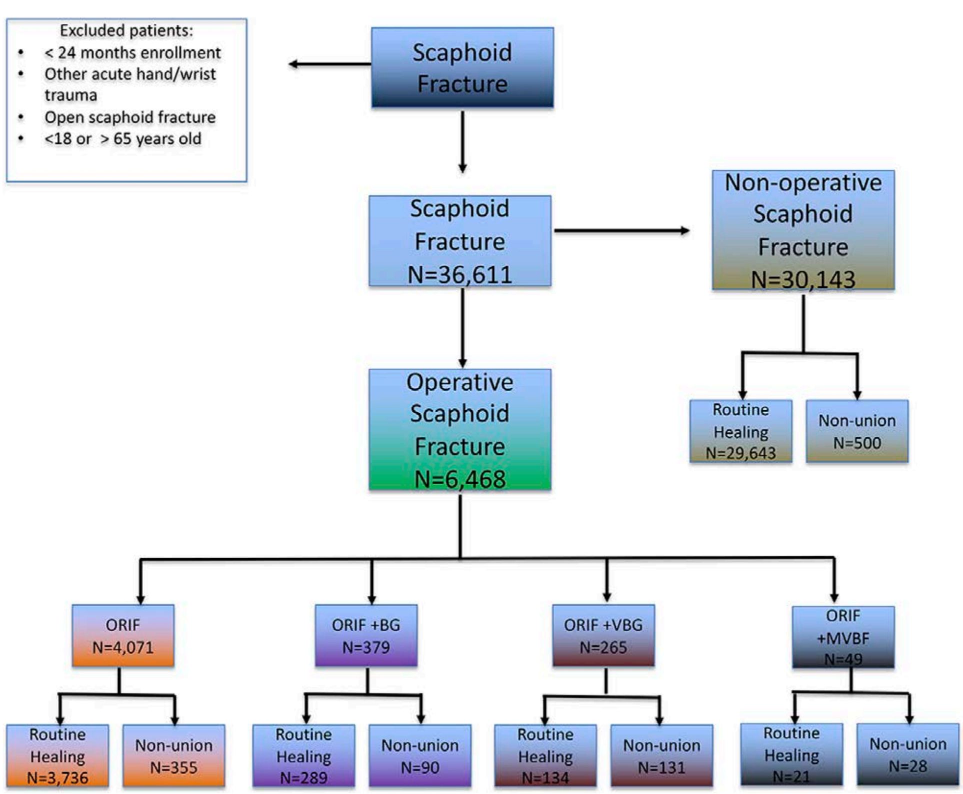

Fig. 1. Study flow demonstrating inclusion and exclusion criteria for the study groups.

were divided into ORIF, open reduction and internal fixation with bone graft (ORIF + bone graft), open reduction and internal fixation with vascularized bone graft (ORIF and VBG), and open reduction and internal fixation with free microvascular anastomosis (ORIF with MVA). We performed descriptive statistics based on surgical treatment and patient demographic variables (eg, gender, age, region of residence, smoking status, employment status, and insurance type). An analysis of the association between the previously described patient variables and the type of treatment received was conducted using a χ^2 test.

Resource Utilization

Operative and nonoperative groups were followed up for 24 months to assess resource utilization. We calculated the mean number of clinic visits, imaging beyond the index radiograph, operating room costs, and occupational therapy session costs. We determined the costs associated with each patient based on their claim records. For example, the cost of a radiograph was determined by identifying the cost of a single claim record with the CPT code for the radiograph. The total charges for each clinic visit encounter in the patient's record were used to determine the cost of an office visit. Procedural cost data are comprised of the total cost of the encounter and include primarily the charges for the surgeon, operating room, and anesthesia. We used all the charges (radiographs, clinic visits, occupational therapy visits, and surgery) to calculate a mean cost associated with a particular treatment. Using the analysis of variance test, we compared the resource utilization between nonunion and routine healing subgroups among the surgical and nonsurgical patients. Statistical analyses were performed using SAS 9.4 software (SAS Institute, Inc., Cary, N.C.) and R 4.0.3 software [R Core Team (2020)].

Table 1. Demographic Data for Nonoperative Scaphoid Fractures

Characteristic	Scaphoid Fractures Managed Nonoperatively: Routine Healing	Scaphoid Fractures Managed Nonoperatively: Nonunion	*P*
Number	29,643 (98.34)	500 (1.66)	
Total	30,143		
Sex			
Male	16,963 (57.22)	377 (75.4)	**<0.001**
Female	12,680 (42.78)	123 (24.6)	
Age			
18–34	12,863 (43.39)	248 (49.6)	**0.004**
35–44	4830 (16.29)	84 (16.8)	
45–54	6044 (20.39)	97 (19.4)	
55–64	5906 (19.92)	71 (14.2)	
Insurance			
PPO	17,966 (60.61)	306 (61.2)	0.766
Comprehensive	528 (1.78)	11 (2.2)	
HMO	3727 (12.57)	63 (12.6)	
POS	2079 (7.01)	39 (7.8)	
Other	5343 (18.02)	81 (16.2)	
Smoking status			
Never smoker	27,360 (92.30)	440 (88)	**0.001**
Smoker	2283 (7.70)	60 (12)	
Employment status			
Employed	14,339 (48.37)	236 (47.2)	0.928
Retiree	1509 (5.09)	24 (4.8)	
Disability	63 (0.21)	1 (0.2)	
Other/unemployed	13,732 (46.32)	239 (47.8)	
Region			
Northeast	6536 (22.05)	107 (21.4)	0.964
North Central	6178 (20.84)	103 (20.6)	
South	9822 (33.13)	163 (32.6)	
West	6521 (22.00)	116 (23.2)	
Bone stimulator use			
Invasive	2 (0.003)	2 (0.4)	
Noninvasive	31 (0.10)	6 (1.2)	

RESULTS

Nonoperatively Managed Scaphoid Fractures

A total of 36,611 patients with scaphoid fractures were identified; 30,143 were managed nonoperatively. Most patients were men ($P < 0.001$), young working-age individuals, and 18–34 years old ($P = 0.0004$). Among patients managed nonoperatively, nonunion was diagnosed in 500 (1.66%). A greater proportion of nonunion patients were smokers compared with those who went on the routine healing (12% versus 7.7%), $P = 0.001$ (Table 1). Bone stimulators were used in less than 2% of nonoperatively managed patients with nonunion. Examination of insurance type, employment status, and regional location did not demonstrate a significant difference in the development of nonunion among nonoperatively managed patients.

Operatively Managed Scaphoid Fractures

Of the patients with scaphoid fractures, 6468 were managed operatively, and nonunion was diagnosed in 1211 (19%). There were 4783 patients who had records for the 24-month study period and were included in the in-depth analysis. A greater proportion of the surgical patients were men, $P = 0.008$ (Table 2). Most patients who underwent surgery were between ages 18 and 34 (<0.001). Smoking was not prohibitive for surgery and overall, and 10% of operative patients were identified as smokers (Table 2). When grouped together, smoking increased the chances of nonunion in a statistically significant manner among operatively managed scaphoid fracture patients, $P = 0.034$ (Table 2). Examination of the time lag between fracture diagnosis and surgery among patients who went on to routine healing and those who developed nonunion revealed a significant difference between groups (routine healing 28 days versus nonunion 183 days, $P < 0.001$) (Table 2). Bone stimulator use among the surgical groups with nonunion was also less than 2%.

The following operative procedures were performed for scaphoid fracture patients: ORIF of scaphoid fracture (ORIF), ORIF + bone graft, ORIF and VBG, and ORIF with MVA. Among the most performed surgical procedures for scaphoid fractures, the prevalence of nonunion after surgical management was as follows: ORIF, 8.2%; ORIF + bone graft, 23%; ORIF + VBG, 49%; and ORIF +

Table 2. Demographic Data for Operatively Managed Scaphoid Fractures

	Scaphoid Fractures Managed Operatively		
Characteristic	**Routine Healing**	**Nonunion**	***P***
Number	5257 (81.28)	1211 (18.72)	
Total	6468		
Sex			
Male	4295 (81.70)	1028 (84.89)	**0.008**
Female	962 (18.30)	183 (15.11)	
Age			
18–34	3676 (69.93)	921 (76.05)	**<0.001**
35–44	653 (12.42)	128 (10.57)	
45–54	516 (9.82)	114 (9.41)	
55–64	412 (7.84)	48 (3.96)	
Insurance			
PPO	3226 (61.37)	752 (62.10)	0.785
Comprehensive	70 (1.33)	13 (1.07)	
HMO	604 (11.49)	133 (10.98)	
POS	378 (7.19)	79 (6.52)	
Other	979 (18.62)	234 (19.32)	
Smoking status			
Never smoker	4749 (90.34)	1069 (88.27)	**0.034**
Smoker	508 (9.66)	142 (11.73)	
Employment status			
Employed	2736 (52.04)	616 (50.87)	0.434
Retiree	171 (3.25)	31 (2.56)	
Disability	6 (0.11)	1 (0.08)	
Other/unemployed	2344 (44.59)	563 (46.49)	
Region			
Northeast	1018 (19.36)	232 (19.16)	0.833
North Central	1158 (22.03)	271 (22.38)	
South	1734 (32.98)	404 (33.36)	
West	1253 (23.83)	288 (23.78)	
Bone stimulator use			
Invasive	2 (0.04)	2 (0.17)	
Noninvasive	42 (0.80)	18 (1.49)	
Duration from initial fracture, mean ± SD	28.4 ± 61.39	183.83 ± 202.57	**<0.001**

MVA, 57% (Table 3). ORIF + VBG and ORIF + MVA are rarely utilized as the first operation in the treatment of a scaphoid fracture unless specific circumstances demand it. Delayed patient presentation (>3 months) and/or location of the fracture (proximal pole fractures) may explain these findings. The higher rates of nonunion among the patients who underwent more advanced procedures (VBG and MVA) underpin the difficulty of these cases and need for early indicators of delayed bone healing.

Resource Utilization among Operatively and Nonoperatively Managed Scaphoid Fractures

We individually characterized resource utilization among nonoperatively and operatively managed patients with scaphoid fractures who went on to routine healing or nonunion. As expected, nonunion patients had a greater number of clinical visits across all treatments when compared with those who went on to routine healing ($P < 0.001$) (Table 4). Patients who underwent ORIF + VBG with routine healing had the lowest mean number of clinic visits at 6.93 visits compared with those who underwent ORIF with bone graft, mean number of clinic visits at 14.7 visits ($P < 0.001$) (Table 4). Patients with routine healing after nonoperative management had the lowest mean number of plain radiographs (three) and CTs (one) compared with those who underwent free vascularized bone graft who had a mean 13 plain radiographs and four CTs during their treatment course ($P < 0.001$) (Table 4). Occupational therapy is used variably for scaphoid fracture patients managed operatively and nonoperatively; there was no statistically significant difference in the mean number of sessions, but those who were treated with ORIF + MVA had the longest duration of OT, 420 days ($P < 0.001$) (Table 4). Overall, it is resource intensive to provide care for scaphoid fracture patients; the mean costs to care for these patients ranged from $10,967 for a nonoperative patient with routine healing compared with $33,166 for a patient who underwent vascularized bone graft with nonunion (Fig. 2).

DISCUSSION

In the current study, we found that bone stimulator use among nonoperatively and operatively managed scaphoid nonunion patients was less than 2%. This technology has been around for some time; in 1979, the FDA approved the first electrical bone stimulation device for the

Table 3. Demographic Characteristics based on Surgical Intervention

Characteristic	Open Reduction with or without Internal Fixation (25,628)			Open Reduction with or without Internal Fixation (25,628) + Bone Graft (20,902 or 20,900)			Insertion of Vascular Pedicle into Carpal Bone (25,430)			Bone Graft with Microvascular Anastomosis (20,962)		
	Routine Healing	Nonunion	*P*	Routine Healing	Nonunion	*P*	Routine Healing	Nonunion	*P*	Routine Healing	Nonunion	*P*
Number	3736	335		289	90		134	131		21	28	
Total	4071			379			265			49		
Sex			0.115									
Male	2992 (80.09)	280 (83.58)		243 (84.08)	74 (82.22)	0.679	123 (91.79)	115 (87.79)	0.280	17 (80.95)	25 (89.29)	0.412
Female	744 (19.91)	55 (16.42)		46 (15.92)	16 (17.78)		11 (8.21)	16 (12.21)		4 (19.05)	3 (10.71)	
Age			**0.001**									
18–34	2501 (66.94)	252 (75.22)		208 (71.97)	68 (75.56)	0.716	112 (83.58)	110 (83.97)	0.960	15 (71.43)	23 (82.14)	0.231
35–44	499 (13.36)	44 (13.13)		29 (10.03)	8 (8.89)		12 (8.96)	11 (8.4)		3 (14.29)	5 (17.86)	
45–54	402 (10.76)	26 (7.76)		30 (10.38)	10 (11.11)		7 (5.22)	8 (6.11)		2 (9.52)	0 (0)	
55–64	334 (8.94)	13 (3.88)		22 (7.61)	4 (4.44)		3 (2.24)	2 (1.53)		1 (4.76)	0 (0)	
Insurance			0.462									
PPO	2264 (60.6)	197 (58.81)		182 (62.98)	53 (58.89)	0.257	77 (57.46)	90 (68.7)	0.081	9 (42.86)	17 (60.71)	0.212
Comprehensive	50 (1.34)	3 (0.90)		5 (1.73)	3 (3.33)		2 (1.49)	0 (0)		1 (4.76)	1 (3.57)	
HMO	439 (11.75)	33 (9.85)		28 (9.69)	8 (8.89)		13 (9.7)	14 (10.69)		4 (19.05)	1 (3.57)	
POS	277 (7.41)	28 (8.36)		15 (5.19)	9 (10)		18 (13.43)	8 (6.11)		3 (14.29)	1 (3.57)	
Other	706 (18.90)	74 (22.09)		59 (20.42)	20 (22.22)		24 (17.91)	19 (14.5)		4 (19.05)	8 (28.57)	
Smoking Status			0.581									
Never smoker	3370 (90.20)	299 (89.25)		269 (93.08)	82 (91.11)	0.541	120 (89.55)	113 (86.26)	0.410	17 (80.95)	22 (78.57)	0.838
Smoker	366 (9.80)	36 (10.75)		20 (6.92)	8 (8.89)		14 (10.45)	18 (13.74)		4 (19.05)	6 (21.43)	
Employment status			0.463									
Employed	1946 (52.09)	165 (49.25)		163 (56.40)	40 (44.44)	0.127	77 (57.46)	63 (48.09)	0.223	10 (47.62)	15 (53.57)	0.680
Retiree	127 (3.40)	9 (2.69)		4 (1.38)	1 (1.11)		3 (2.24)	2 (1.53)		0 (0)	0 (0)	
Disability	4 (0.11)	0 (0)		0 (0)	0 (0)		1 (0.75)	0 (0)		0 (0)	0 (0)	
Other/ unemployed	1659 (44.40)	161 (48.06)		122 (42.21)	49 (54.44)		53 (39.55)	66 (50.38)		11 (52.38)	13 (46.43)	
Region			0.751									
Northeast	720 (19.27)	73 (21.79)		68 (23.53)	17 (18.89)	0.702	35 (26.12)	30 (22.9)	0.351	6 (28.57)	3 (10.71)	0.277
North Central	823 (22.03)	74 (22.09)		61 (21.11)	19 (21.11)		28 (20.9)	21 (16.03)		4 (19.05)	10 (35.71)	
South	1260 (33.73)	106 (31.64)		89 (30.8)	26 (28.89)		45 (33.58)	41 (31.3)		7 (33.33)	11 (39.29)	
West	869 (23.26)	78 (23.28)		68 (23.53)	26 (28.89)		23 (17.16)	36 (27.48)		4 (19.05)	3 (10.71)	
Bone stimulator use												
Invasive	1 (0.03)	0 (0)		1 (0.35)	0 (0)		0 (0)	0 (0)		0 (0)	0 (0)	
Noninvasive	24 (0.64)	5 (1.49)		2 (0.69)	1 (1.11)		2 (1.49)	6 (4.58)		0 (0)	0 (0)	

Table 4. Resource Utilization of Scaphoid Fracture Patients

	Scaphoid Fracture Management										
	Nonoperatively Managed		Open Reduction with or without Internal Fixation (25,628)		Open Reduction with or without Internal Fixation (25,628) + Bone Graft (20,902 or 20,900) 379		Insertion of Vascular Pedicle into Carpal Bone (25,430)		Bone Graft with Microvascular Anastomosis (20,962)		
Medical Services	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	*P*
Total	29,643	500	3736	335	289	90	134	131	21	28	
Clinic visit (99,211–99,215)											
Number, mean ± SD	9.83 ± 11.24	14.43 ± 14.94	7.39 ± 8.72	13.28 ± 16.24	7.56 ± 8.47	14.71 ± 21.14	6.93 ± 6.97	12.62 ± 16.97	11.2 ± 15.82	11.14 ± 10.38	<0.001
Costs per session (USD), mean ± SD	87.35 ± 53.92	89.78 ± 77.43	87.67 ± 48.45	83.34 ± 45.56	88.62 ± 41.48	83.31 ± 37.92	85.09 ± 56.01	91.52 ± 55.42	88.18 ± 26.10	80.12 ± 34.96	0.091
Imaging											
XR (73,100 and 73,110)											
Number, mean ± SD	3.38 ± 2.53	5.95 ± 4.41	6.07 ± 3.44	12.04 ± 7.38	6.83 ± 3.67	11.82 ± 8.47	6.56 ± 3.56	11.82 ± 7.82	8.4 ± 6.29	13.14 ± 8.80	<0.001
Costs per session (USD), mean ± SD	50.78 ± 62.95	56.95 ± 103.81	51.21 ± 67.61	51.16 ± 59.19	49.96 ± 83.29	53.70 ± 69.52	46.42 ± 45.80	49.06 ± 51.19	40.66 ± 40.03	59.26 ± 62.38	0.214
Percentage of having XR	84.84	92.6	97.64	99.70	98.62	98.89	98.51	100	95.24	100	
MRI (73,218, 73,219, and 73,220)											
Number, mean ± SD	1.38 ± 0.76	1.86 ± 1.07	1.25 ± 0.53	1.86 ± 1.07	1 ± 0	2.25 ± 1.26	1	0	1	0	0.65
Costs per session (USD), mean ± SD	550.71 ± 578.17	826.75 ± 886.56	508.27 ± 349.44	758.22 ± 698.52	917.53 ± 246.23	996.39 ± 715.04	1014.49	N/A	441	N/A	0.096
Percentage of having MRI	1.18	1.4	0. 64	2.09	0.69	4.44	0.75	0	4.76	0	
CT (73,200, 73,201, and 73,202)											
Number, mean ± SD	1.69 ± 0.93	2.37 ± 2.02	1.95 ± 1.23	3.33 ± 2.68	2.16 ± 1.67	2.66 ± 2.00	2.11 ± 1.31	3.62 ± 2.96	2 ± 0.82	4.33 ± 3.81	<0.001
Costs per session (USD), mean ± SD	336.82 ± 372.28	371.96 ± 392.30	365.90 ± 430.42	379.99 ± 375.82	369.49 ± 371.21	415.09 ± 429.88	340.66 ± 307.88	315.36 ± 306.03	479.57 ± 841.28	438.81 ± 379.81	<0.001
Percentage of having CT	13.92	40.8	32.09	68.96	50.17	71.11	55.22	75.57	47.62	75	
Occupational therapy											
Number, mean ± SD	6.69 ± 11.74	6 ± 8.40	6.25 ± 11.36	7.86 ± 13.66	6.69 ± 13.47	5.29 ± 9.39	3.90 ± 5.39	4.90 ± 7.29	1.25 ± 0.5	13.7 ± 20.32	0.377
Costs per session (USD), mean ± SD	52.03 ± 151.38	43.84 ± 50.78	52.03 ± 50.47	58.67 ± 52.95	47.89 ± 59.62	51.14 ± 47.35	55.66 ± 42.22	43.26 ± 51.29	36.7 ± 26.79	41.63 ± 23.90	0.802

(Continued)

Table 4. Continued

Medical Services	Scaphoid Fracture Management: Nonoperatively Managed		Open Reduction with or without Internal Fixation (25,628)		Open Reduction with or without Internal Fixation (25,628) + Bone Graft (20,902 or 20,900) 379		Insertion of Vascular Pedicle into Carpal Bone (25,430)		Bone Graft with Microvascular Anastomosis (20,962)		*P*
	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	Routine Healing	Nonunion	
Duration from initial fracture, mean ± SD	240.67 ± 216.03	274.86 ± 213.94	168.27 ± 182.66	330.30 ± 203.29	259.79 ± 303.64	320.91 ± 206.89	149.77 ± 60.65	282.13 ± 181.92	157.4 ± 164.22	420.26 ± 251.64	<0.001
Procedural costs (USD), mean ± SD	N/A	N/A	2893.82 ± 3111.98	2828.39 ± 3305.40	938.79 ± 653.68	861.11 ± 1060.98	1087.71 ± 2274.51	1022.85 ± 1148.80	5088.05 ± 4856.8	7734.88 ± 11096.69	<0.001
Bone stimulator use											
Cost of therapy	132.45 ± 253.76	226.13 ± 453.79	60.15 ± 61.65	102.02 ± 134.88	92.97 ± 105.01	N/A	89.14 ± 2.39	107.78 ± 103.61	N/A	N/A	

treatment of nonunion and congenital pseudarthroses.[15] Since then, multiple noninvasive external devices have been developed that deliver different modes of energy including electric and ultrasonic stimulation. Several companies manufacture FDA-approved bone stimulators that deliver electromagnetic energy including Zimmer Biomet (devices OsteGen and OsteoGenM) and Don Joy Global (device CMF OL1000). Among the ultrasonic devices, Exogen manufactured the first FDA-approved device, and more recently, Orthofix received approval for Accelstim, an additional low-intensity ultrasound bone stimulator.[18]

Bone stimulators have been used to treat scaphoid nonunion since 1982 with one study demonstrating a 75% healing rate among patients whose previous surgery failed.[19] After this, Bora et al[20] demonstrated a 71% healing rate after 12 weeks of noninvasive bone stimulator use among scaphoid nonunion patients. In a recent randomized study, the authors examined the impact of one dose of intraoperatively administered electrical bone stimulation following ORIF with nonvascularized bone graft among scaphoid nonunion patients; the addition of bone stimulator resulted in a greater proportion of healed patients by 12 weeks postoperatively.[21] Bone stimulators have also been used to accelerate bone healing among acute scaphoid fractures; Mayr et al[22] compared the effects of adjunctive bone stimulation (ultrasound) on acute fracture healing and found radiographic healing in the experimental group at 43 days compared with 62 days in the control group; this was statistically significant. Hannemann et al[23,24] demonstrated similar findings among acute scaphoid fractures treated with pulsed electromagnetic bone stimulation. In addition, they examined the cost-effectiveness of pulsed electromagnetic field bone stimulators among acute scaphoid fracture patients and found a reduction in total working days lost from 12.9 to 9.8 days.[23,24] Despite its use to treat acute fractures, current indications for the use of bone stimulators in the US include failed bone graft procedures, patient refusal of surgery, or patient who is unsafe for surgery. Extrapolating from this, bone stimulators may play a role in faster clinical and radiographic healing among nonunion patients, and that may translate to earlier return to activities. Once initiated, patients should anticipate at least 3–4 months (sometimes longer) of treatment to determine its effect.

Bone stimulators have been used as an adjunct to healing among femur fracture nonunions as well as spinal fusion nonunions. Hughes and Anglen[25] surgically implanted 121 direct current bone stimulators for nonunion fractures and arthrodesis patients and found that 85% had radiographic and/or clinical healing of their nonunion site at 7.1 months. Nolte et al[26] examined the effect of low-intensity ultrasound bone stimulators among a heterogenous group of fracture nonunion patients (tibia, femur, radius, and scaphoid) and found 86% of patients healed, with an average healing time of 152 days.

The low prevalence of bone stimulator use for scaphoid nonunion in the current study is perhaps due in part to increased costs of this technology as well as the stringent, burdensome, and variable requirements for approval by insurance companies. Some surgeons may be unaware of

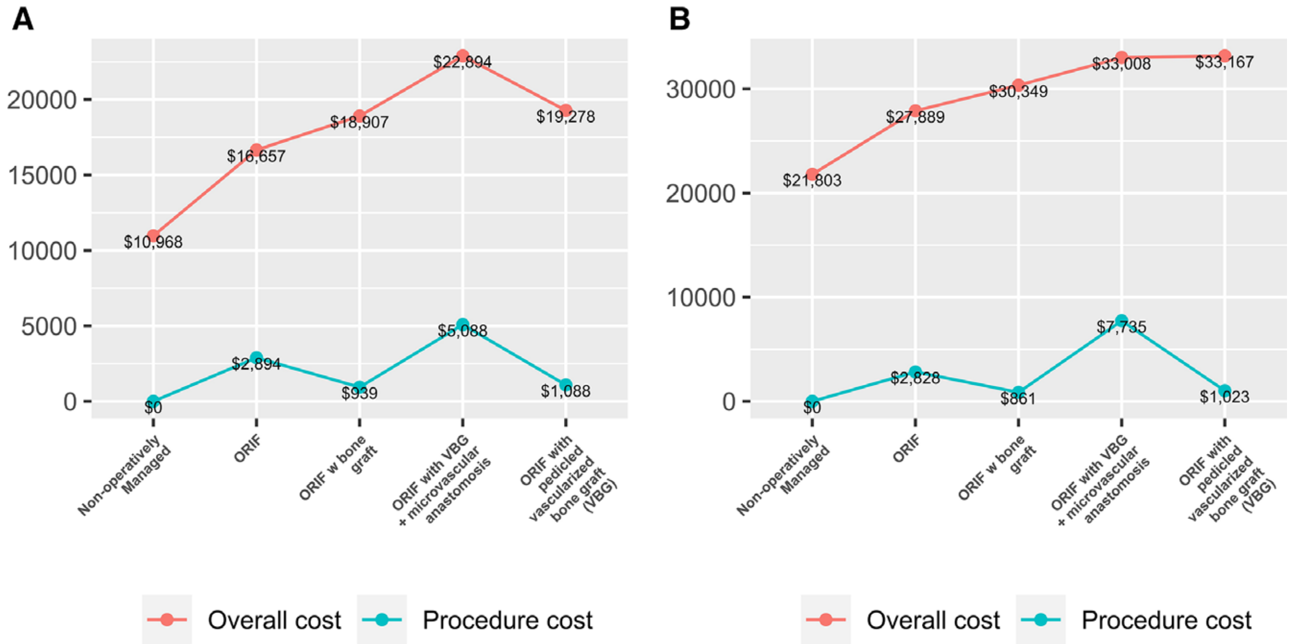

Fig. 2. Costs of fracture healing. A, Mean total costs ($) associated with for scaphoid fractures with routine healing based on treatment choice. B, Mean total costs ($) associated with care for scaphoid fractures with nonunion based on treatment choice.

the appropriate CPT codes (20974: electrical stimulation to aid bone healing, noninvasive and 20979: low-intensity ultrasound stimulation to aid bone healing, noninvasive) and Healthcare Common Procedural Coding System codes (E0747: osteogenesis stimulator, electrical, noninvasive, and other than spinal applications and E0760: osteogenesis stimulator, low-intensity ultrasound, and noninvasive) that are crucial for approval and necessary for claim submission.[27] Huang et al[17] surveyed medical directors representing over 119 million insured patients regarding a hypothetical clinical scenario of delayed bone healing and request for electrical bone stimulator. They found that 84% of insurance companies required specific time frames of delayed healing, 76% required serial plain radiographs, 44% required documentation about lack of infection, 36% required documentation of the size of the fracture gap, and 17% required physicians to document clinical signs of nonunion. With the demands of a busy clinical practice, many surgeons have difficulty fulfilling these requirements, limiting the approval and use of these devices.

Examination of resource utilization among scaphoid fracture patients revealed that operatively and nonoperatively managed patients with nonunion were costly to health care system with mean costs to care for nonunion scaphoid fracture patients that were consistently greater across all surgical treatments (>$10,000) compared with care scaphoid fractures with routine healing ($P < 0.001$). These costs are due in part to the greater number of clinic (outside the global period) and occupational therapy visits, increased frequency of plain radiographs, and use of more advanced imaging [computerized tomography/magnetic resonance imaging (CT/MRI)], as well as the performance of more complex procedures in these groups. Less frequent, advanced imaging at critical intervals can be an avenue to decrease health care expenses.[28–31] External bone stimulator costs vary depending on manufacturer and insurance coverage, but range between $500 and $5000.[32] Button et al[33] performed a systematic review of the literature focusing on the economic analysis of bone stimulator use and found that among tibial fracture patients with delayed healing and/or nonnuion, a total cost savings of $15,00 per case (20-40% reduction) was achieved. Examining our data on resource utilization, it seems feasible to consider the use of bone stimulators in one's treatment algorithm rather than obtaining repeated costly imaging such as MRI or CT, that is, $500–1000/study in patients with nonunion. When considering the health care expenditure among scaphoid nonunion patients, surgeons may consider bone stimulator use in place of repeat CT and/or MRI.

This study has some limitations. Similar to any retrospective administrative data study, this analysis is dependent on the accuracy of the data reported; however, Marketscan is a well-established medical database with proven credibility. The mechanism and location of the scaphoid fracture are unknown in this study group; however, we followed up patients for 24 months and minimized confounders by excluding patients with open fractures and other hand/wrist injuries. Because this is a database study, we do not have the perioperative discussions and clinical goals of the surgeon and patients in the decision to pursue nonoperative or operative treatment. In addition, we do not have data on the patient's clinical examination; although they may have developed nonunion, they may be clinically asymptomatic or "well." Because the Marketscan database provides code-specific data rather than individual patient notes, we were unable to identify how, when, and if patients who used bone stimulators improved. Extrapolating from the randomized control trials in the literature on the use of bone stimulators for scaphoid fractures, we have found that bone stimulators led to some clinical or radiographic improvement among 70%–75% of treated patients which is promising for the patients in whom it was used.[19,20]

As medicine continues to advance and technologies emerge, surgeons must determine how these adjuncts complement traditional treatments and factor into the overall management strategy. The use of bone stimulators to treat scaphoid nonunion patients is relatively low despite some evidence in the literature to suggest its ability to promote bone healing in these circumstances. This underutilization may be related to surgeons' awareness and understanding of the technology, trust in its efficacy, and/or willingness to pursue insurance approval. As more evidence about its usefulness emerges, surgeons may consider this treatment adjunct rather than additional imaging in patients with established nonunion whose previous surgery failed or who have exhausted all operative interventions.

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