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Motion-Restoring Surgery versus Non-Operative Stretch-Assist Devices for Treatment of Joint Contracture: Utilization, Timing, Cost, and Outcomes from Medicare and Commercial Claims

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Research Article

Keywords: joint contracture, motion-restoring surgery, dynamic stretch-assist splint, static progressive splint, turnbuckle/wormgear splint, continuous passive motion, recovery outcomes, healthcare costs, claims-based analysis, Medicare

Posted Date: February 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8555717/v1

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Additional Declarations: Competing interest reported. SS and SB are employees of ArthroResearch LLC; TB is founder and CEO of Ermi LLC.

Abstract

Background

This study aimed to assess national treatment patterns, timing, and costs of interventions for joint contracture using Medicare and commercial claims data. Emphasis was placed on comparing the frequency, cost, and recovery outcomes associated with continuous passive motion (CPM), motion-restoring surgery (MRS), and wearable stretch-assist devices, including dynamic and turnbuckle/wormgear stretch-assist splints.

Methods

A retrospective cohort analysis of the Centers for Medicare & Medicaid Services (CMS) and IBM MarketScan databases (2015–2018) was conducted. Patients diagnosed with contracture of the knee, shoulder, elbow, wrist, or ankle were identified through medical diagnosis codes. Incidence, prescriptive patterns, recovery time, and costs were determined using corresponding claims-based information. Recovery duration was defined as the time from index treatment to the last rehabilitation claim. Comparative analyses were conducted using the Wilcoxon Signed-Rank and Mood's Median tests.

Results

MRS was the predominant treatment across all joints and accounted for the majority of costs associated with contracture care. Across joints, MRS-treated patients experienced significantly higher total costs and longer recovery durations, with an average 234-day delay relative to non-operative care. Wearable dynamic and turnbuckle/wormgear splints were prescribed in fewer than 8% of cases and were typically initiated months after primary surgery and often following MRS. CPM demonstrated no measurable benefit in recovery or prevention of contracture and was associated with higher costs. Only dynamic splint use after elbow fracture was associated with significantly shorter recovery compared to MRS.

Conclusions

Current clinical practice heavily favors MRS despite prolonged recovery and higher expenses. Non-operative mechanical stretch-assist devices are underutilized and typically prescribed too late to influence outcomes suggesting that the healthcare community does not consider them a viable option. The greater adoption of elbow splints may reflect providers' reluctance to use elbow MRS.

Background

Healing after an injury to a joint flows through four distinct phases: 1) hemostasis, 2) inflammatory, 3) proliferative, and 4) remodeling [1]. Failure to complete this sequence can result in joint contracture and loss of motion. Mechanical stress associated with the stretching of a joint is required during the remodeling phase of healing to guide the appropriate cellular and collagen response [1]. Accordingly, stretching is a critical component of the postoperative or postinjury rehabilitation plan. Both insufficient and excessive stretching can disrupt tissue remodeling and result in a joint contracture [1]. Accurate differentiation between joint contracture (M24.5x), ankylosis (M24.6x), and stiffness (M25.6x) is critical, as they are distinct etiologies requiring distinct management strategies. Joint ankylosis describes a fixed motion loss with no possibility of recovery while joint stiffness describes a joint that is hard to move with no motion loss. Neither condition can be addressed through stretching or surgical release.

Motion loss due to joint contracture can severely limit activities of daily living, including self-care, mobility, and workplace function, and can persist for years after surgery or injury [2]. The consequences are particularly severe in older adults, as joint

contracture can lead to institutionalization and permanent disability, but at any age, contracture is associated with delayed recovery and an increased risk of complications [3, 4].

Management strategies for joint contracture have existed for centuries. Non-operative treatment of contracture has evolved from wooden pulleys and ropes to custom turnbuckle casting, to continuous passive motion (CPM), and, more recently, to wearable stretch-assist splints [5–10]. These wearable stretch-assist splints are divided into two categories: dynamic stretch-assist splints and turnbuckle/worm gear stretch-assist splints. The dynamic splints use a constant low load to stretch the joint in one direction, ie, flexion or extension. The turnbuckle/worm gear splints use progressive fixed positioning to force a joint into one direction, ie, flexion or extension. These wearable stretch assist splints have been approved for Medicare reimbursement for over 20 years, each with its own distinct Healthcare Common Procedure Coding System (HCPCS) code within the E1800–E1841 series. Unfortunately, Medicare has named the turnbuckle/wormgear stretch-assist splints using a physical therapy technique called static progressive stretch, which has created confusion in the orthopedic world.

Operative treatment of joint contracture, collectively termed motion-restoring surgery (MRS), includes manipulation under anesthesia (MUA), arthroscopic or open lysis of adhesions, synovectomy, and scar tissue release. Despite the availability of other non-operative treatment options, MRS remains the predominant clinical response to postoperative stiffness [11–15]. While often effective, MRS carries risks of anesthesia, infection, thromboembolic events, and reoperation [16–18]. Previous studies have also shown that MRS is associated with prolonged rehabilitation and elevated costs after total knee arthroplasty (TKA), rotator cuff repair (RCR), knee ligament repair, and fracture repair in the elbow, ankle, and wrist [19–24].

Despite decades of availability, the real-world utilization, timing, and effectiveness of wearable stretch-assist splints remain poorly characterized. Clinical evidence from smaller studies suggests that these devices are most effective when prescribed early in the postoperative course, before secondary fibrosis and adhesions develop [8, 25, 26]. After 20 years of availability, the current clinical adoption of CPM, wearable stretch-assist splints, and MRS needs to be characterized. Clarification of the timing, duration of use, and frequency of these treatments across large, diverse populations is essential for identifying optimal pathways to full joint recovery.

This study addresses the lack of large-scale evidence comparing the use and outcomes of non-operative versus operative treatment of joint contractures. By using large-scale data from both Medicare and commercial databases, this study aimed to:

1. Determine the incidence of joint contracture across major joints (knee, shoulder, ankle, elbow, and wrist)
2. Determine the incidence and costs related to the most common treatment for contracture, motion-restoring surgery (MRS)
3. Evaluate prescriptive patterns and timing of CPM and wearable stretch-assist splints
4. Compare recovery duration and associated costs across treatment modalities
5. Evaluate whether the use of non-operative stretch assist devices is associated with shorter recovery durations and lower costs when compared to MRS.

We hypothesized that earlier or more consistent use of CPM and/or wearable stretch-assist splints for the treatment of joint contracture would be associated with shorter recovery durations and lower treatment costs than motion restoring surgery.

Methods

Study Design

This retrospective cohort analysis used data from two sources: 1) the Centers for Medicare & Medicaid Services (CMS) database (5% random sample, scaled to population incidence); and 2) the IBM MarketScan Commercial Claims and Encounters database. Both datasets include longitudinal healthcare claims linked by a patient identifier, allowing evaluation

of prescriptive behavior and timing, along with associated costs and recovery time. This study was conducted in accordance with the Declaration of Helsinki and was deemed exempt from Institutional Review Board (IRB) review. As the study used previously collected, de-identified data, individual patient consent was not required.

Inclusion Criteria

Patients with ICD-9/10 codes consistent with joint contracture (718.4x, M24.5x) were included if they had at least two consecutive years of insurance coverage. Shoulder adhesive capsulitis (M75.0) and Achilles contracture (M67.0) were grouped with the shoulder and ankle categories, respectively, given their similar clinical courses, which result in motion loss addressable through stretching or release [27–29]. The study period was from January 2015 to December 2018. All costs are presented in U.S. dollars and correspond to the same time period.

Treatment Patterns

Prescription frequencies for wearable stretch-assist devices were determined by examining associated HCPCS codes for dynamic splints and turnbuckle/wormgear splints within the E1800-E1841 series of codes (Table 1). The incidence of MRS was determined using Current Procedural Terminology (CPT) codes for procedures such as MUA, arthroscopic/open lysis of adhesions, arthroscopic/open synovectomy, or arthroscopic/open scar tissue debridement/release for each joint type (Table 2). The incidence of CPM could be determined only for the knee, as it is the only joint with its own unique billing code (E0935). All other joints are combined into a single code (E0936).

Table 1
HCPCS codes for dynamic and turnbuckle/wormgear (SPS) stretch-assist splints.

E1800- Elbow Dynamic Splint
E1801- Elbow SPS Splint
E1802- Forearm Sup/Pro Dynamic Splint
E1805- Wrist Flex/Ext Dynamic Splint
E1806- Wrist Flex/Ext SPS Splint
E1810- Knee Dynamic Splint
E1811- Knee SPS Splint
E1815- Ankle Dynamic Splint
E1816- Ankle SPS Splint
E1818- Forearm SPS Splint
E1840- Shoulder Dynamic Splint
E1841- Shoulder SPS Splint

Table 2
Motion restoring surgery CPT codes for the shoulder joint.

CPT Code	Description
23700	Manipulation under anesthesia, shoulder joint, including the application of a fixation apparatus, but excluding dislocation
29805	Arthroscopy, shoulder, diagnostic, with or without synovial biopsy (separate procedure)
29820	Arthroscopy, shoulder, surgical, synovectomy, partial
29821	Arthroscopy, shoulder, surgical, synovectomy, complete
29822	Arthroscopy, shoulder, surgical, debridement, limited
29823	Arthroscopy, shoulder, surgical, debridement, extensive
29825	Arthroscopy, shoulder, surgical, with lysis and resection of adhesions, with or without manipulation
23020	Release shoulder joint

Outcome Measures

The primary outcomes were incidence of each treatment modality, treatment cost, and recovery duration (defined as the time from the index surgery or treatment to the last physical or occupational therapy claim). A secondary outcome was the timing of device initiation relative to surgery or MRS.

Data Analysis

Data were analyzed using the R statistical programming language (version 4.3.3). Given the large sample size, results are presented as medians and interquartile ranges. The Wilcoxon Signed-Rank and Mood's Median tests were used to compare recovery time and cost between modalities. Statistical significance was set at $p < 0.05$.

Results

Incidence

The incidence of joint contracture diagnosis, MRS, and wearable splint prescriptions was calculated from the CMS database. From 2015–2018, an estimated 114,830 patients were diagnosed annually with joint contracture across five major joints (Table 3). MRS was the dominant treatment, exceeding splint use at least threefold in all joints except the elbow. For example, among 47,255 shoulder contracture cases, 32,120 underwent MRS, while only 375 received any wearable stretch-assist splint (Fig. 1). Alternatively, in the elbow, prescriptive frequency was essentially equal between MRS (1,155 cases/year) and wearable stretch-assist splints (1,435 cases/year). This analysis included 3,165 Ermi Knee Extensionaters (791/year) prescribed to Medicare patients from 2015 to 2018, lumped into E1811, representing 38.5% of the 2,055 knee turnbuckle/wormgear splints prescribed to Medicare patients each year. (Note that the Ermi Knee Extensionaters are not a turnbuckle/wormgear stretch-assist splint.) However, the analysis excluded Ermi Flexionaters, as they were not prescribed to commercial or Medicare patients during the same period. The use of CPM devices was far more common than both dynamic splints and turnbuckle/wormgear splints, with a nearly sevenfold higher frequency than splints (Fig. 2).

Table 3
Number of yearly Medicare claims estimated from a 5% sample.

	Shoulder	Wrist	Knee	Ankle	Elbow
Joint Contracture	47,255	28,615	16,690	16,630	5,640
Motion Restoring Surgery	32,120	27,225	17,720	3,760	1,155
Dynamic Splint Use	260	1,075	3,560	610	935
Turnbuckle/wormgear Splint Use	115	305	2,055	150	505

Costs

Treatment for joint contracture represented a substantial economic burden, exceeding $750 million annually in the Medicare population (Table 4). The majority of these dollars were related to MRS ($630 million or 83% of all costs). Wearable splints accounted for < 1% of total expenditures.

Table 4
Estimate of yearly Medicare dollars spent on patients with the diagnosis of joint contracture, the use of motion restoring surgery, dynamic stretch-assist splint or turnbuckle/wormgear stretch-assist splint from a 5% sample of Revenue Center Total Charge Amount in the CMS Database.

	Mean Yearly $ Spent					
	Shoulder	Wrist	Knee	Ankle	Elbow	Total
Contracture (M24.5x)	$282,247,706	$136,820,704	$98,522,071	$212,570,904	$28,000,604	$758,161,989
Motion Restoring Surgery	$165,615,000	$175,070,580	$88,541,026	$192,861,033	$8,066,861	$630,154,500
Dynamic Splint Use	$20,844	$858,284	$1,846,547	$1,053,319	$622,722	$4,401,715
Turnbuckle/wormgear Splint Use	$10,309	$132,720	$1,260,167	$126,585	$299,734	$1,829,494

Treatment Efficacy

Across the shoulder, knee, and ankle, CPM showed no improvement in recovery duration, contracture prevention, or avoidance of MRS (Tables 5–7). CPM patients had median costs 1.1–15 times higher and recovery times 1.1–7.2 times longer than non-CPM cohorts. The use of CPM in patients with a unilateral TKA increased contracture diagnosis (M24.56) and the need for MRS (Table 6). The findings were similar for the shoulder (Table 7).

Table 5
Cost and recovery time comparison between patients treated with CPM and those treated without CPM.

	Shoulder RCR	Wrist Fx	Knee TKA	Ankle Fx	Elbow Fx
Median Cost No CPM	$2,933	$2,329	$4,186	$2,543	$2,819
Median Cost CPM	$3,498	$8,988	$4,562	$3,505	$42,565
Difference Range	($330 to $854)	($16,051 to – $4,126)	($237 to $533)	($3,184 to – $3,965)	($51,584 to – $21,819)
Total Cost p-value	< 0.01	< 0.01	< 0.01	0.82	< 0.01
Median PT Days No CPM	153	98	122	88	100
Median PT Days CPM	169	542	147	630	434
Difference Range	(26 to – 3)	(554 to 104)	(9 to 0)	(1184 to – 43)	(387 to 129)
PT days p-value	0.11	0.01	0.06	0.06	0.01
No CPM Patients (n)	14,627	6,050	8,575	7,109	2,669
CPM Patients (n)	320	8	2,361	3	11
Total Patients (n)	14,947	6,058	10,936	7,112	2,680

Table 6
Effect of continuous passive motion (CPM) usage on subsequent joint contracture diagnosis.

Total Knee Arthroplasty		
	CPM	No CPM
Contracture	11%	7%
Motion Restoring Surgery	15%	5%

Table 7
Effect of continuous passive motion (CPM) usage on subsequent need for motion restoring surgery.

Shoulder Rotator Cuff Repair		
	CPM	No CPM
Contracture	8%	7%
Motion Restoring Surgery	10%	5%

Dynamic stretch-assist splints were prescribed in fewer than 8% of cases and were not associated with a significant change in treatment cost or duration for knee, shoulder, wrist, or ankle contractures. Total costs for patients who received a dynamic stretch-assist splint were 1.7-4 times higher than for patients who did not receive a dynamic stretch-assist splint. Out of 14,947 unilateral RCR patients, only 25 were prescribed a shoulder dynamic stretch-assist splint. Its use did not significantly change the need for MRS (Table 7). Furthermore, among those RCR patients who underwent MRS, 66% had a splint prescribed after surgery. Patients using the dynamic splint for knee TKA, shoulder RCR, elbow fracture, and wrist fracture had the device prescribed after MRS in over 50% of cases (Table 8). Use of a dynamic stretch-assist splint was not associated with a change in recovery duration after TKA, RCR, wrist fracture, or ankle fracture (Fig. 3). However, in treating elbow

fractures, dynamic stretch-assist splinting was associated with shorter recovery time and lower total costs than MRS (Fig. 4, Table 8). Across all joints, dynamic stretch-assist splints were prescribed late in the recovery timeline, with treatment starting on average over 5 months after primary surgery (Table 9).

Table 8
Cost and recovery time comparison between patients treated with dynamic low-load progressive stretch (LLPS) splints and those treated without LLPS.

	Shoulder RCR	Wrist Fx	Knee TKA	Ankle Fx	Elbow Fx
Median Cost Normal Course	$2,945	$2,316	$4,226	$2,540	$2,777
Median Cost LLPS	$11,777	$8,320	$7,543	$5,822	$4,841
Difference Range	($5,950 to $9,386)	($2,123 to $6,388)	($2,041 to $3,475)	($1,049 to $7,149)	($1,300 to $2,952)
Total Cost p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Median PT Days Normal Course	153	98	123	88	98
Median PT Days LLPS	359	421	264	328	203
Difference Range	(-54 to 135)	(44 to 234)	(29 to 83)	(-35 to 292)	(15 to 87)
PT Days p-value	0.64	< 0.01	< 0.01	0.15	< 0.01
Median Cost MRS	$22,498	$17,075	$11,249	$30,319	$30,689
Median Cost LLPS	$12,827	$15,654	$7,543	$9,684	$14,950
Difference Range	(-$1,625 to -$9,804)	(-$968 to -$5,922)	(-$2,472 to -$4,443)	(-$5,035 to -$20,527)	(-$7,171 to -$15,718)
Total Cost p-value	< 0.001	0.01	< 0.001	< 0.001	< 0.001
Median PT Days MRS	451	265	321	357	333
Median PT Days LLPS	359	421	264	328	203
Difference Range	(8 to -251)	(135 to -26)	(25 to -36)	(108 to -320)	(-16 to -189)
PT Days p-value	0.07	0.19	0.68	0.60	**0.02**
MRS Patients (n)	714	510	979	232	75
LLPS Patients (n)	25	41	183	10	71
Total Patients	14,947	6,058	10,936	7,112	2,680

	Shoulder RCR	Wrist Fx	Knee TKA	Ankle Fx	Elbow Fx
Mean Days from Primary to splint	115.8	155.2	143	253	112.6
% of Patients with both MRS and splint	24%	34%	44%	30%	13%
% of Patients with splint ordered after MRS	66%	57%	69%	33%	56%

Turnbuckle/wormgear stretch-assist splints were prescribed even less frequently than dynamic stretch-assist splints. In a series of 14,947 patients, only one shoulder turnbuckle splint was prescribed to a patient two months after RCR surgery, without a diagnosis of shoulder contracture or adhesive capsulitis. Four out of the 11 turnbuckle splints used in patients with TKA were prescribed before their primary surgery (unilateral TKA). The seven turnbuckle stretch-assist splints used after TKA

did not have a significant impact on postoperative recovery compared with MRS (Table 10). Although sample sizes were small, the use of a turnbuckle/wormgear stretch-assist splint was associated with lower costs than MRS, with a comparable recovery duration.

Table 10
Cost and recovery time comparison between static progressive splints and motion restoring surgery.

	Shoulder RCR	Wrist Fx	Knee TKA	Ankle Fx	Elbow Fx
Median Cost MRS		$12,061	$11,249		$20,061
Median Cost SPS		$8,864	$10,200		$6,178
Difference Range		(-$12,018 to $2,040)	(-$6,639 to $3,353)		(-$19,981 to $3,192)
Total Cost p-value		0.24	0.42		0.09
Median PT Days MRS					
Median PT Days SPS					
Difference Range					
PT days p-value		0.13	1.0		0.96
MRS Patients (n)	0	510	979	0	75
SPS Patients (n)	1	6	11	0	8
Total Patients (n)	14,947	6,058	10,936	7,112	2,680

Discussion

Despite being on the market and available with an HCPCS code for over 20 years, wearable stretch-assist splints are underutilized as a treatment option for joint contractures, suggesting that the healthcare community does not consider them a viable option. On the other hand, MRS remains both the most commonly used and the most expensive treatment for joint contracture. Across the knee, shoulder, ankle, and wrist, MRS was prescribed far more often than any stretch-assist splint and accounted for more than 80% of contracture-related costs. These findings reflect a continued reliance on surgical management, even though non-operative alternatives, such as prolonged physical therapy, exist. The observed 234-day average delay in recovery after MRS highlights the long-term costs and quality-of-life implications for patients and payers, reinforcing the need for earlier, more effective non-operative treatment as an alternative to MRS.

Despite a decades-long history of Medicare coverage and clinical validation, providers prescribed wearable stretch-assist splints in fewer than 8% of contracture patients across all joints except the elbow. Moreover, providers initiated use too late, an average of 5 months after the primary surgery, and after MRS in more than half of cases. The data show that splints are being used reactively rather than proactively as a primary non-operative option. When applied too late, the ability to prevent further procedures, accelerate recovery, and reduce healthcare costs is greatly diminished (Fig. 5). Mechanical stretch therapy is a critical element of the remodeling phase of joint healing. It works by signalling to cells which collagen to produce, Type I vs Type III, and in which direction to be laid down. Stretching provides these “stress lines” for remodeling, with its effectiveness greater when initiated during the proliferation phase of healing. Clearly, MRS restarts the joint-healing process by sending it back to the hemostasis phase or, at least, to the inflammatory phase, resulting in a marked delay in recovery. Stretching after MRS should be delayed until the proliferative phase to allow joint inflammation to settle. Joint healing is not complete until the remodeling phase is completed.

The presence of joint contractures, or delayed joint motion recovery, has plagued the healthcare community for centuries. With the advent of CPM for intra-articular joint healing in the 1980s, providers adopted it as both a preventive and reactive treatment for this problem [30]. Given the low prescription rate of wearable stretch-assist splints, possibly due to difficulty of

use, the continued use of CPM suggests that the healthcare community seeks an easy-to-use, effective non-operative treatment for motion loss due to joint contractures. Interestingly, this study confirms that the use of the CPM was not associated with improved patient outcomes in unilateral TKA, shoulder RCR, elbow fractures, wrist fractures, or ankle fractures [31–35], despite the healthcare community's faith in its efficacy. This may merely reflect the ease of CPM use, the positive feedback patients using CPM provide to providers, or the success seen among a subset of CPM users.

The elbow fracture cohort, in which non-operative treatment with wearable stretch-assist splinting demonstrated faster recovery and lower cost than MRS, illustrates the opportunity for success when devices are prescribed at the appropriate time for the appropriate joint. Unlike in other joints, the elbow showed near parity between surgical and non-operative prescriptions, suggesting greater clinician acceptance of wearable stretch-assist splint use, perhaps due to the known complexity of elbow MRS [36–38]. However, even in the elbow, many wearable stretch-assist splints were prescribed late in recovery, limiting their potential benefit.

Limitations

Claims-based analyses cannot capture all clinical nuances. Coding variability, lack of functional outcome data, and absence of patient-level context limit granularity. Recovery time was estimated from therapy claim closure, potentially resulting in an underestimate of residual stiffness. Nonetheless, the large sample size, dual-database validation, and consistent cross-joint trends strengthen the reliability of these findings. Results regarding any stretch-assist device use may partly reflect selection bias toward more severe joint contracture or joint motion loss cases.

Conclusions

Treatment of joint contracture in the United States remains dominated by expensive surgical procedures that prolong recovery and drive the high cost of healthcare spending. Despite being on the market and available with an HCPCS code for over 20 years, wearable stretch-assist splints are underutilized as a treatment option for joint contractures, suggesting that the healthcare community does not consider them a viable option. The greater adoption of wearable stretch-assist splints for treating elbow joint contractures may reflect providers' reluctance to use elbow MRS.

Declarations

Ethics approval and consent to participate:

This retrospective study was determined to be exempt from Institutional Review Board (IRB) review by Sterling IRB. As this observational study used previously collected, de-identified data, consent to participate was not applicable.

Consent for publication:

Not Applicable

Competing Interests

SS and SB are employees of ArthroResearch LLC; TB is founder and CEO of Ermi LLC.

Funding:

No specific funding was received for this research.

Author Contribution

SS, SB, and TB contributed to study design, analysis, interpretation, and manuscript preparation. All authors approved the final version.

Data Availability

Data are proprietary to IBM MarketScan and CMS and available upon reasonable request under license.

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Figures

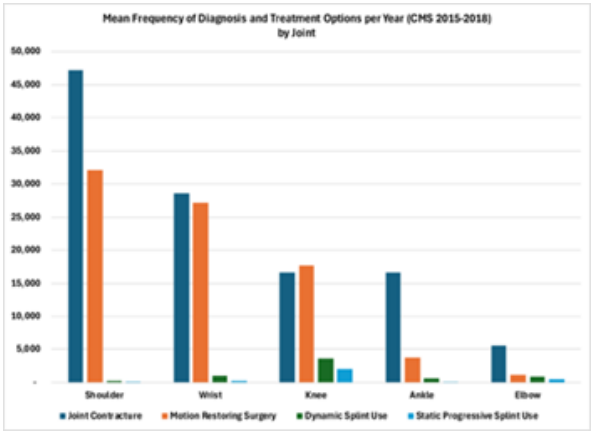


Figure 1

Yearly data calculated from a 5% sample of CMS frequency data (2015-2018). The Medicare treatment of choice for all motion loss due to joint contractures is Motion Restoring Surgery.

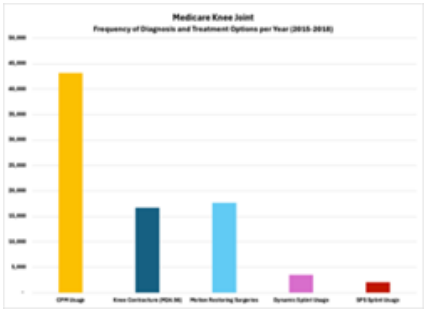


Figure 2

Providers are still prescribing continuous passive motion (CPM) for the prevention of knee contractures at a 12.1 times greater rate than dynamic stretch-assist splints despite the lack of proven benefit with CPM (Medicare/CMS data).

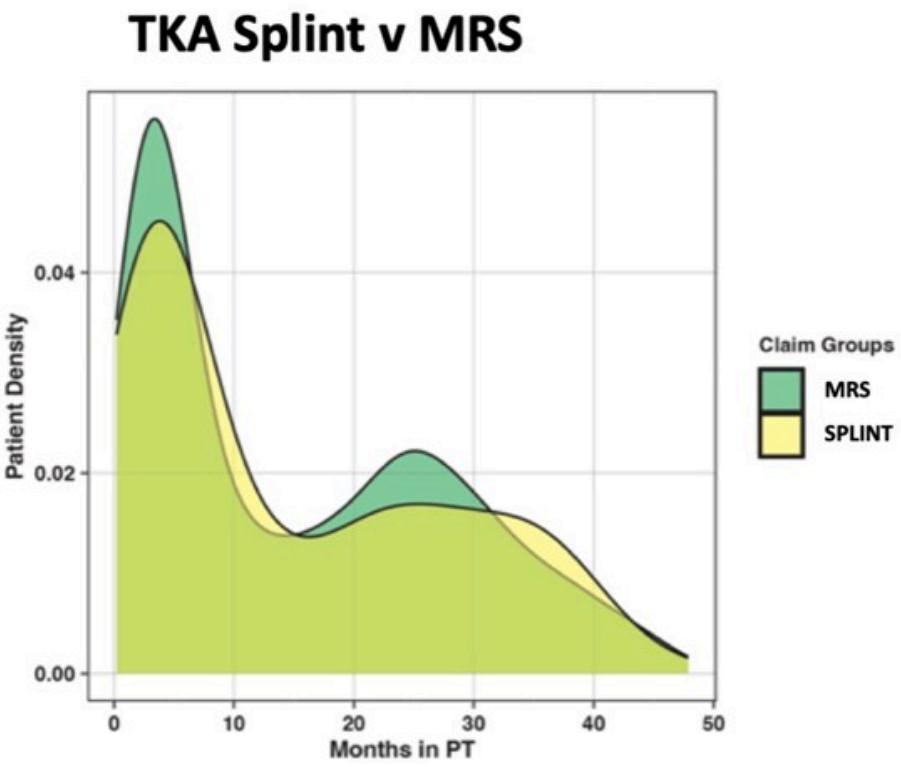


Figure 3

Knee (TKA) recovery durations show no difference between dynamic stretch-assist splinting and MRS.

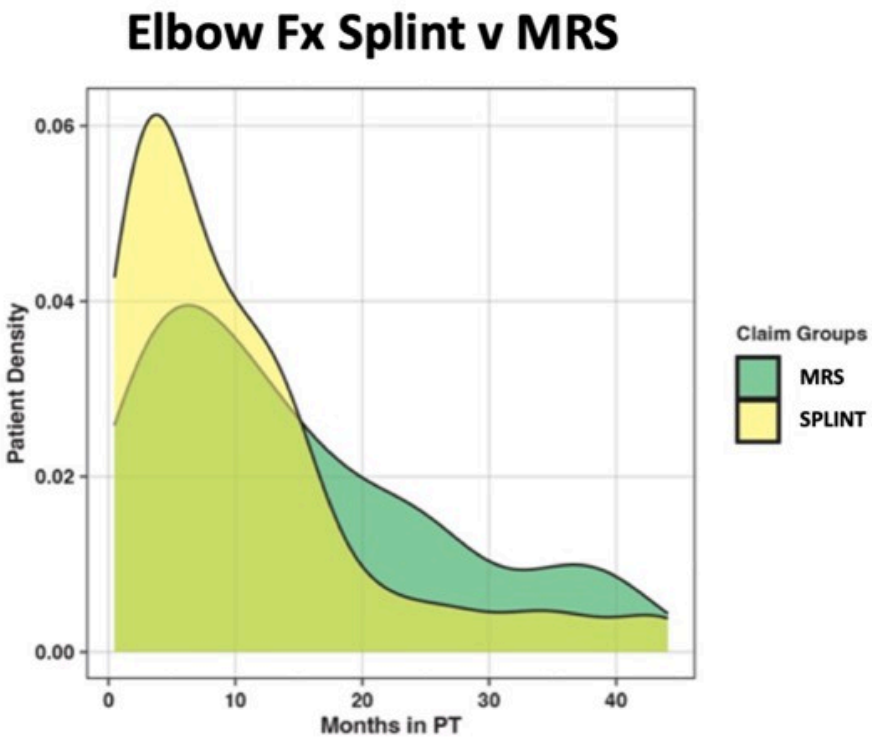


Figure 4

Elbow fracture recovery improved significantly with dynamic stretch-assist splinting versus MRS ($p < 0.02$); however, one must be careful using the median as a representation of the distribution (Mood's Median Test $p < 0.10$) rather than mean due to the large sample size.

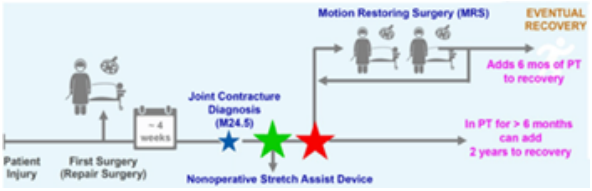


Figure 5

A stretch assist device must be prescribed BEFORE motion restoring surgery and it must be given time to work to be most effective. Furthermore, they should be initiated early to have the most effect.