A Survey of Treatment Trends for Acute Quadriceps Tendon Ruptures Among North American Surgeons

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Background: To date, little clinical evidence exists to support a specific surgical technique or postoperative rehabilitation protocol for quadriceps tendon ruptures. With a lack of evidence-based superiority, assessment of clinical practices and surgeon preferences is pertinent.

Purpose: To describe the current surgical technique and rehabilitation preferences among members of the Canadian Orthopaedic Association and American Orthopaedic Society for Sports Medicine pertaining to acute quadriceps tendon rupture.

Study Design: Cross-sectional study.

Methods: Orthopaedic staff members of the Canadian Orthopaedic Association and American Orthopaedic Society for Sports Medicine were invited to complete an internet-based survey composed of 26 questions assessing current trends in the management and rehabilitation of acute quadriceps tendon rupture. Survey questions were developed after a thorough review of current literature. Survey responses were analyzed and reported using descriptive statistics (absolute values, frequencies, and percentages) where appropriate. Statistical comparisons and contrasts between Canadian and American surgeons were made using chi-square analyses and Student *t* tests.

Results: A total of 264 surgeons participated in the survey (136 Canadians; 128 Americans). Canadian surgeons were more likely to obtain a preoperative ultrasound as compared with Americans (43.0% vs 6.7%; $P < .00001$), while American respondents were more likely to obtain magnetic resonance imaging scans (65.8% vs 10.2%; $P < .00001$). The transosseous drill hole technique was the most commonly utilized (70.2%); the suture anchor technique was used 20.6% of the time. Canadian respondents trended toward a higher use of transosseous tunnels; however, this was not statistically significant (75.8% vs 64.2%; $P = .068$). American respondents were more likely to utilize suture anchors (27.5% vs 14.1%; $P = .0096$). Most respondents advanced range of motion goals stepwise in 2-week intervals of 30° (Canadians, 54.0% vs Americans, 58.5%; $P = .3091$); timing of range of motion initiation varied.

Conclusion: Among North American surgeons who responded to this study, the transosseous technique was the most commonly used, and range of motion was generally advanced in a 2-week stepwise fashion. We found several differences in practice between Canadian and American respondents, including the type of preoperative imaging and the frequency of using the suture anchor technique.

Keywords: quadriceps tendon rupture; surgical technique; rehabilitation protocol

Quadriceps tendon ruptures (QTRs) are debilitating injuries routinely treated by orthopaedic surgeons, with an incidence of 1.37 per 100,000, a male to female ratio of 4.2:1, and a mean patient age of 51.1 years.[6,7] Rupture occurs via an eccentric contraction of the quadriceps muscle on a flexed knee, such as trying to catch a fall, and is often associated with systemic comorbidities, such as diabetes, chronic renal failure, rheumatoid diseases, obesity, anabolic steroid use, and medications (eg, statins and quinolones).[11,12,31] Ruptured tendons are also associated with degenerative histopathological changes.[13]

Given the poor outcomes with chronically neglected QTR, surgical intervention in the form of primary tendon-to-bone repair is the treatment of choice.[14,27,29] Controversy remains regarding the best method to achieve repair; some evidence has suggested suture anchor (SA) repair methods are biomechanically stronger than transosseous (TO) suture techniques, though this has not correlated to a clinical difference in outcomes or rerupture in QTR.[24] Furthermore, TO techniques remain more cost-effective than SA techniques.[24]

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Timing of postoperative mobilization is a second area of controversy; traditionally these injuries were treated with prolonged immobilization, but more recent trends have included earlier or even immediate range of motion (ROM), with significant variability in protocols.[2,35] While early motion is thought to promote healing, some evidence has suggested that it may lead to increased secondary surgery and extensor lag.[30]

To date, there remains little clinical evidence to support a specific surgical technique or postoperative rehabilitation protocol. With a lack of evidence-based superiority, assessment of clinical practices and surgeon preferences is pertinent. The primary goal of this study was to conduct a survey of orthopaedic surgeons from Canada and the United States to gain an understanding of their preferences regarding surgical technique and postoperative rehabilitation of acute QTRs. Our secondary goal was to compare these preferences between Canadian and American surgeons. We hypothesized that the TO technique would be most commonly utilized and that the majority of rehabilitation protocols would begin ROM exercises at 2 weeks and advance stepwise with 2-week 30° intervals.

METHODS

Study Participants

Invited study participants included 1030 active Canadian surgeon members of the Canadian Orthopaedic Association (COA) and 3806 active members of the American Orthopaedic Society for Sports Medicine (AOSSM), of which 3540 were American and 89.3% were surgeon-members (K. Boyer, AOSSM director of research, personal communication, 2020). Both orthopaedic associations were contacted to ensure distribution of the survey to a large number of North American surgeons. This study was deemed not to require research ethics board approval.

Survey Design

The survey was developed after a thorough review of current literature surrounding surgical management and rehabilitation of acute QTR. The survey comprised 26 questions: 23 multiple-choice questions, 2 numeric or text responses, and 1 question on degree of satisfaction using a 5-point Likert scale (see supplemental material). Nine multiple-choice questions also allowed for the participants to select "other" and give a text response if the preferred choice was not indicated. "Other" responses were then reviewed after study completion and recategorized into a provided response where appropriate. Questions focused on preoperative patient workup, surgical technique specifics, and postoperative rehabilitation protocols and immobilization. This survey was trialed with 4 fellowship-trained orthopaedic surgeons not involved in the study to ensure survey comprehensiveness and feasibility. Questions were then revised, as needed, and the survey was distributed.

Survey Distribution

An email invitation was distributed via SurveyMonkey.com. The COA and AOSSM had separate guidelines for survey distribution, and we adhered to the guidelines for each of them. Distribution of the email link for Canadian surgeons was completed 3 times via COA Dispatch Research Edition (April-July 2019): an initial email, followed by a reminder email at 1 and 3 months. American distribution was completed twice via AOSSM Survey Research Update dispatch: an initial email, followed by a reminder email. It was also listed on the AOSSM website during that time (December 2019-April 2020).

All responses were deidentified, and no personal data were collected.

Data Analysis

Responses were collected within the SurveyMonkey database and were reported using descriptive statistics (absolute values, frequencies, and percentages) where appropriate. Total summative data were analyzed; comparisons and contrasts between Canadian and American respondents were also made. Statistical comparisons were made using chi-square analyses and Student t tests. Significance was set at $P < .05$.

RESULTS

A total of 264 members responded to the survey: 136 Canadians and 128 Americans. This represents approximately 13.2% of Canadian and 3.6% of American members of the

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Ethical approval for this study was waived per the Women's College Hospital Assessment Process for Quality Improvement Projects pathway.

COA and AAOS, respectively. Participants from both groups had similar levels of experience, with 51.2% in practice for ≥10 years. Of the participants, 96% had completed at least 1 acute quadriceps tendon repair in the past 24 months.

The frequency distribution of respondents by the number of QTRs they fix per year is represented in Figure 1. Results indicated that 67% of respondents fix <5 acute QTRs per year and have fixed, on average, 34 in their careers to date.

Preoperative Investigation

Respondents were asked what (if any) preoperative imaging investigations they obtain routinely before repairing a QTR (Figure 2). Standard knee radiographs were the most common, with 91.1% of respondents routinely obtaining these preoperatively. Canadian respondents were more likely than Americans to obtain an ultrasound (43.0% vs 6.7%; $P < .00001$), while Americans were more likely to obtain a magnetic resonance imaging (MRI) scan (65.8% vs 10.2%; $P < .00001$). A similar number of Canadian and American respondents obtained a radiograph of the contralateral side (6.5%) or no imaging modality (1.6%).

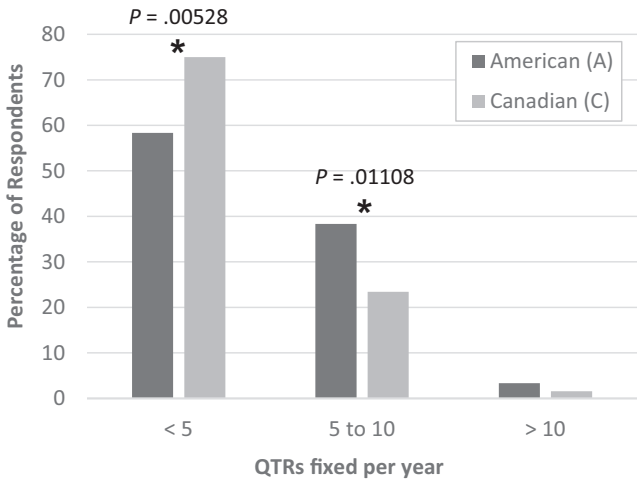

Figure 1. Mean number of acute quadriceps tendon ruptures (QTRs) fixed per year by surgeons. *Statistically significant difference between groups ($P < .05$).

Surgical Technique

With a mean 70.2% use among all respondents, TO was the most commonly utilized surgical technique, while the SA technique was used 20.6% of the time (Figure 3). Canadian respondents trended toward a higher use of TO tunnels as their preferred surgical technique; however, this was not statistically significant ($P = .068$). American respondents were more likely to use SA as their preferred surgical technique (27.5% vs 14.1%; $P = .0096$). A similar number of Canadians and Americans utilized a combined technique (TO + SA; 8.9%). When American and Canadian cohorts were combined, there was no correlation between number of years in practice and SA use ($P = .10$). In the Canadian cohort, there was a statistically significant increased use of the SA technique among respondents with >10 years of practice ($P = .02$).

The breakdown of surgical technique specifics suggested that the majority of respondents using the TO technique primarily employ a 3–drill hole technique in the patella with high-strength suture configuration (60.6%); other techniques utilizing 1, 2, or ≥4 drill holes were used infrequently. The exact TO surgical technique was not specified in 33% of respondents. Combined techniques (TO + SA) were primarily described as 3 drill holes plus 2, 3, or an unspecified number of anchors. The primary repair adjunct was a retinacular suture repair (87.4%); mesh or autograft tendon was used <2% of the time in both groups. There was

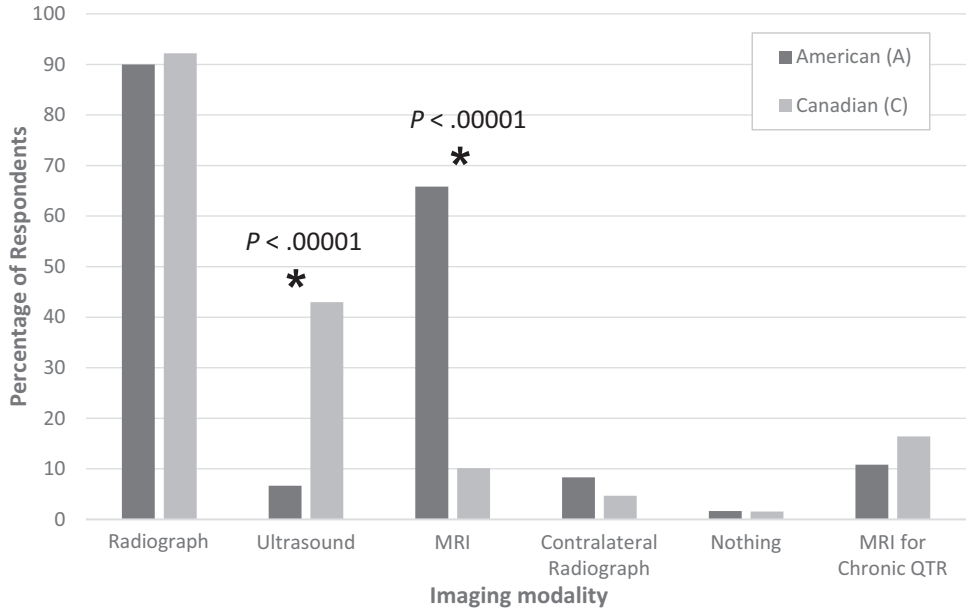

Figure 2. Preoperative imaging modalities obtained. *Statistically significant difference between groups ($P < .05$). MRI, magnetic resonance imaging; QTR, quadriceps tendon rupture.

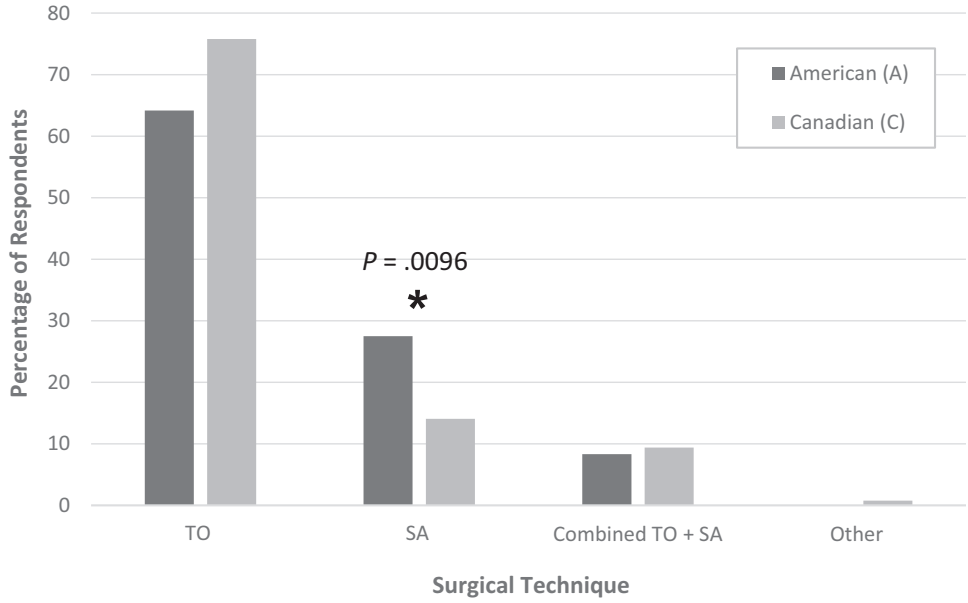

Figure 3. Primary surgical technique utilized by surgeons. *Statistically significant difference between groups ($P < .05$). TO, transosseous suture technique; SA, suture anchor technique

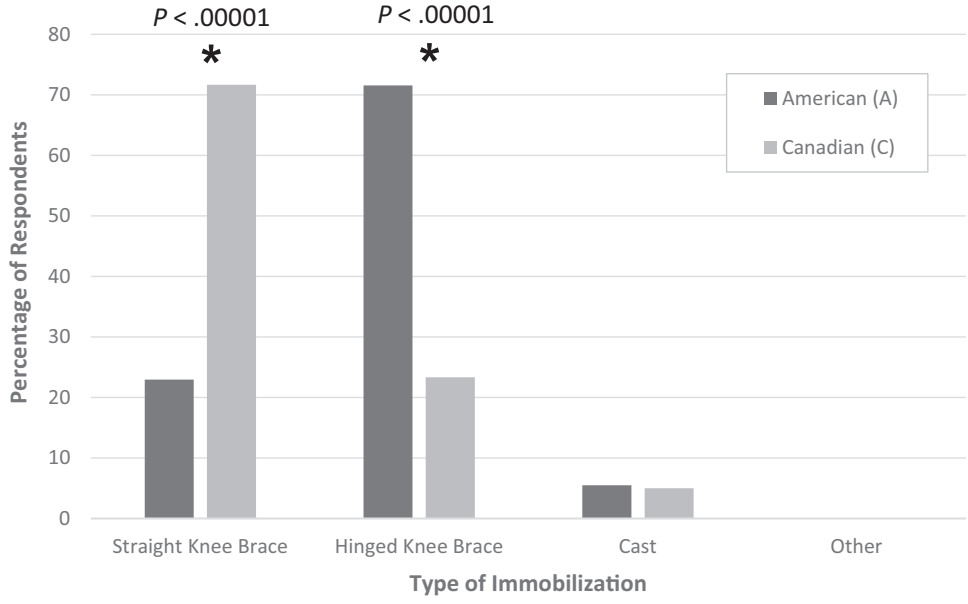

Figure 4. Initial postoperative immobilization method. *Statistically significant difference between groups ($P < .05$).

no statistical significance between groups with regard to surgical technique specifics.

While the majority of respondents did not deflate the tourniquet before tensioning the QTR repair, Canadians were more likely than Americans to do this (53.3% vs 67.9%; $P = .024$). Most believed that it was important to flex the knee intraoperatively after repair to assess integrity (92.2%); 56.9% of American respondents used this as a guide for their therapy protocol, while 40.8% of Canadians did the same ($P = .015$). Overall, 8% of Americans and 17% of Canadians who flexed the knee intraoperatively believed that the repair should remain stable to 90° of passive flexion. If it was believed that there was undue tension on the repair through early motion, postoperative rehabilitation was restricted for 92% of Americans and 83% of Canadians.

Postoperative Protocol

As shown in Figure 4, initial postoperative bracing consisted of a straight-knee immobilizer by 71.7% of Canadian

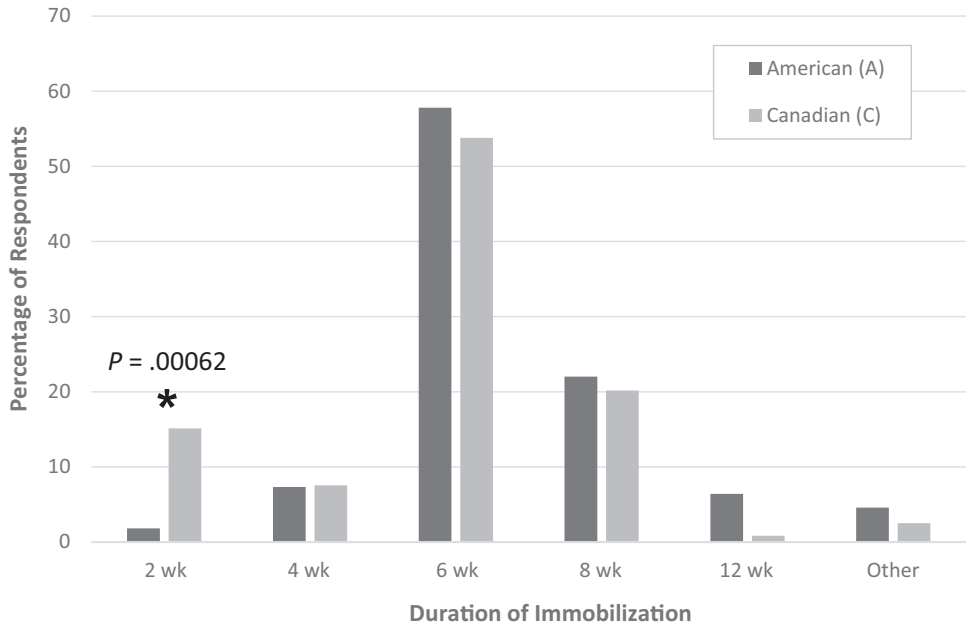

Figure 5. Duration of postoperative immobilization. *Statistically significant difference between groups ($P < .05$).

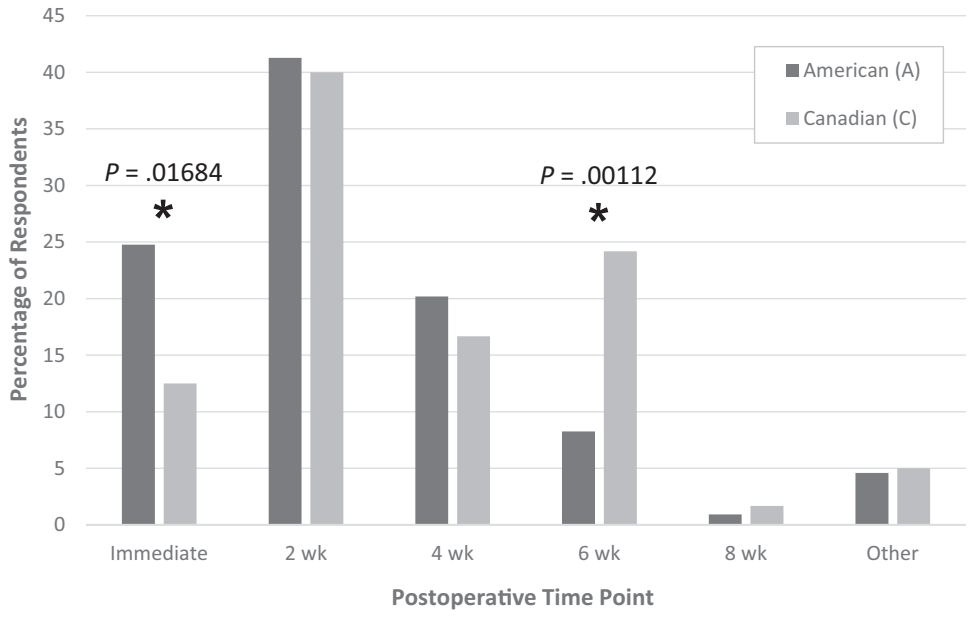

Figure 6. Initiation of range of motion exercises. *Statistically significant difference between groups ($P < .05$).

and 22.9% of American respondents. In contrast, 71.6% of Americans placed patients immediately into a hinged knee brace, while 23.3% of Canadians did so ($P < .00001$). The majority of respondents continued postoperative bracing for 6 weeks (55.8%) to 8 weeks (20.2%) (Figure 5). Initiation of immediate full weightbearing in a brace was recommended by 71.4%. The next most common recommendation was partial/touch weightbearing in a straight-leg brace for 2 weeks (12.3%).

Initiation of ROM exercises varied across both groups, as seen in Figure 6. We found that 41% of respondents initiated ROM at 2 weeks. Americans were more likely to allow immediate ROM (24.8% vs 12.5%; $P = .017$), whereas Canadians were more likely to wait 6 weeks (24.2% vs 8.3%; $P = .0011$). The majority of respondents advanced ROM goals in a stepwise fashion of 2-week intervals of 30° (Canadians, 54.0% vs Americans, 58.5%; $P = .3091$); the next most common rehabilitation protocol was dependent on intraoperative ROM

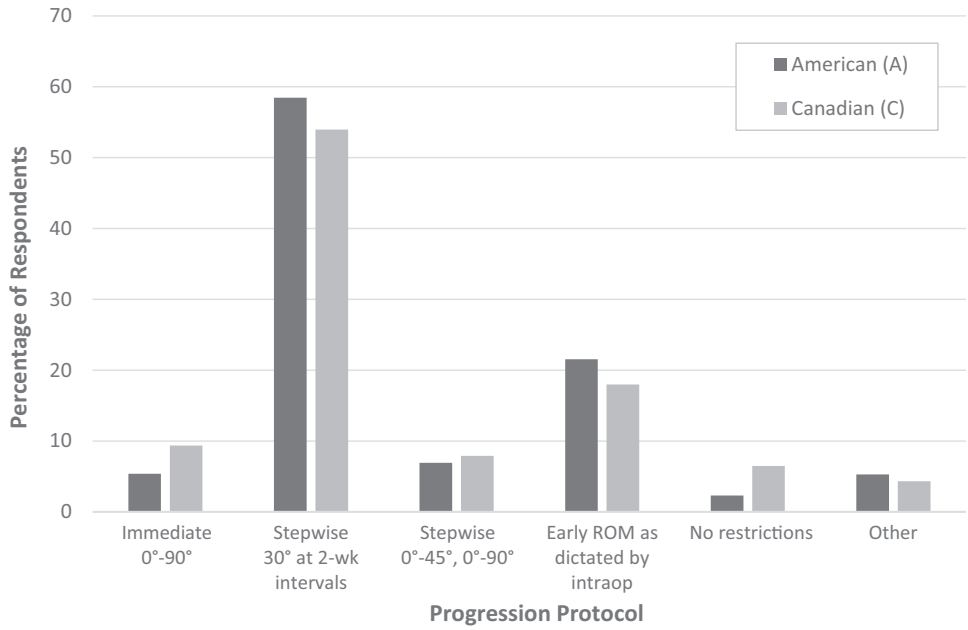

Figure 7. Primary protocol for progression of range of motion (ROM). Intraop, intraoperative.

(19.8%) (Figure 7). Sixty-six percent of Americans reduced ROM progression in patients with high-risk comorbidities, such as type 2 diabetes, chronic renal failure, or rheumatoid arthritis; 45.8% of Canadians did the same ($P = .002$).

Outcomes and Patient Satisfaction

On a 5-point Likert scale, American respondents were more likely to report that they were "very satisfied" with their patients' outcomes (66.1% vs 35.8%; $P < .0001$), whereas Canadian respondents were more likely to report that they were "satisfied" (59.2% vs 30.3%; $P < .0001$). Both groups had a >95% response rate for either "very satisfied" or "satisfied" patient outcomes. A nearly equal distribution of respondents believed that their patients regained approximately 75% to 100% of their full ROM (72.9%) at a mean 3 to 6 months postoperatively (52.9%). Of the American respondents, 19% believed that full ROM was achieved by 3 months, as opposed to 7.5% of Canadians ($P = .0083$). Americans were more likely to report a low incidence of extensor lag, with >95% stating that less than a quarter of their patients had residual lag; 83% of Canadians reported the same ($P = .002$). The majority of patients returned to sports or labor-intensive work between 6 and 9 months postsurgery (59.3%). A significantly smaller number of Canadian respondents performed any revision operations for stiffness (8.3% vs 24.8%; $P = .0007$). The proportion of Canadian and American respondents who had operated on a quadriceps rerupture was similar (44.7%).

DISCUSSION

Among all North American respondents, the TO surgical technique was the most commonly utilized (70.2%), while the SA technique was more typically used among Americans versus Canadians ($P = .0096$). The majority of all respondents advanced ROM in a 2-week stepwise fashion (56.1%). Initiation of ROM varied between American and Canadian respondents, with Americans more likely to advance immediately ($P = .017$) and Canadians more likely to wait up to 6 weeks ($P = .0011$). We identified several other differences in practice between Canadian and American respondents, including the type of preoperative imaging and postoperative bracing.

Overall management of QTR continues to present in a variety of ways, with no standardized consensus on optimal surgical technique or rehabilitation protocol.[24] Our current understanding of QTR is limited to retrospective or prospective studies with small patient numbers, and there is a lack of long-term, high-level clinical outcome studies comparing surgical techniques and rehabilitation strategies. To gain an understanding of the current landscape of management and assess the need for further research, we sought to survey North American surgeons. This study therefore describes the current trends in management of acute QTR among North American surgeons. The current survey asked detailed questions regarding all aspects of care for QTR, from diagnosis to surgical management and rehabilitation. To our knowledge, a study of this nature has not been completed to date.[35]

In preoperative workup of acute QTR, static ultrasound has historically demonstrated excellent sensitivity, while MRI has been shown to be more specific, particularly in patients who have partial ruptures or are obese, as ultrasound is an operator-dependent modality.[22,32] Recent evidence by Foley et al[10] indicated that ultrasound is equally sensitive, specific, and accurate for the identification of high-grade partial and complete QTRs, especially when aided by dynamic knee flexion and extension during

examination. Canadian respondents were significantly more likely to utilize ultrasound as a presurgical diagnostic tool. This is likely reflective of the higher cost of MRI as well as its availability in Canada; comparatively, the United States has approximately 4.2 times more MRI scanners per million people, allowing for more rapid access.[34] Thus, while both imaging modalities are highly sensitive, care should be taken to ensure limited false-positive results with ultrasound, possibly with the addition of dynamic ultrasound testing or further assessment using MRI in cases of diagnostic uncertainty. Of course, advanced imaging should not be substituted for a thorough, focused clinical examination of patients with suspected QTR. Perfitt et al. have demonstrated that clinical examination has a sensitivity of 0.94 with a positive predictive value of 0.79; this positive predictive value rose to 0.82 with simple radiographic signs suggestive of QTR.[22]

According to the results of our study, TO remains the most commonly utilized surgical technique, though American respondents were significantly more likely to use SA than were Canadians. Evidence for SA fixation as a noninferior treatment continues to grow, mostly from small retrospective and prospective studies.[4,8,9,24] To date, a single biomechanical study has shown evidence of better ultimate failure loads and less gap formation with the SA technique as compared with the TO technique, but this has not translated into a measured clinical difference in outcomes in QTR.[23] Recent level 3 evidence regarding patellar tendon ruptures did display a lower rerupture rate in patients with repair using an SA versus TO technique.[20] According to Terhune et al,[33] the average cost (in American dollars) of an SA procedure in 2016 ranged from $75 to $1775, with a mean of $403. Particularly in a universal single-payer public health care system such as the Canadian system, the significantly higher cost associated with an SA over TO procedure may discourage its use without proven clinical superiority. The American system is public-private and may not experience the same financial constraints with equipment usage.[26] Use of augmentation techniques, such as mesh or graft, was limited among Canadian and American respondents. This was also likely related to financial constraints and a lack of proven clinical superiority, with evidence limited to case studies and surgical technique articles and often in the scenario of chronic tears, failed repairs, and quadriceps tendon tears associated with total knee arthroplasty.[5,15,17,19] Finally, there was no correlation between years in practice and SA use when Canadian and American data were combined. Canadian data did, however, reveal a statistically significant increase in SA use among surgeons with >10 years in practice. This may have been related to factors such as increased SA use in a surgeon's elective practice. Overall, when it comes to surgical technique, further high-level comparative studies are required to definitively answer the question of clinical superiority.

Postoperative immobilization may additionally be affected by health care economics, as Canadians were more likely to utilize a less expensive method of bracing throughout the course of treatment. Additional reasoning for the disparity in straight versus hinge brace use among Canadian and American respondents was not identified; aside from cost-related factors, surgeon preference or education may also play a role.

Postoperative rehabilitation typically follows a path of immediate or partial weightbearing for 2 weeks, followed by full weightbearing. Generally, initiation and advancement of ROM occurred in a stepwise fashion, though the timing of these was highly variable, with Americans more likely to initiate ROM early and Canadians more likely to initiate it later. This is found across the literature as well, where no standardized postoperative program exists.[2] In a recent systematic review, Serino et al[30] demonstrated that early mobilization and ROM resulted in higher rates of adverse events and extensor lag and trended toward a higher additional surgery rate. Of note, this included all extensor mechanism soft tissue repairs and was not stratified into QTR versus patellar tendon ruptures. To our knowledge, we are unaware of any clinical studies that adequately show that early ROM in patients with acute QTR leads to decreased rates of stiffness. The majority of rehabilitation programs have been described in case reports and series,[16,25,28,37] with only 1 case report noted to provide a detailed rehabilitation protocol paired with functional objectives and return-to-sports goals.[35] To date, no validated postoperative protocol exists within the literature.

Satisfaction after treatment for QTR varies in the literature but is generally indicated as good to excellent in most patients from a sampling of small studies. Boudissa et al[3] reported a 97% return of full ROM, a Lysholm score of 94, and a 97% return to previous activity in a group of 102 patients with a mean age of 55 years. These results are similar to those stated by O'Shea et al[21] (return to prior activity, 95%; functional score, 22.9/25; ROM, 0°-116°; 1 extensor lag), West et al[36] (Lysholm, 92; return to prior activity, 100%; ROM, 120°), and Brossard et al[4] (Lysholm, 92; ROM, 128°; return to work, 100%), while Elkin et al[9] cited slightly lower satisfaction scores: 67% in SA and 88% in TO cases, with respective Lysholm scores of 63 and 72.8 and a slightly higher rate of rerupture (12%). Mille et al[18] found overall satisfaction to be 82%, with 36.4% of patients satisfied and 45.4% very satisfied. In a cohort with higher-demand performance requirements, as seen in a retrospective review of 14 National Football League players with acute QTR, there was evidence of a much lower return to play at the same level (50%).[2] While we were unable to question individual patients in the current study, the general assessment of satisfaction and return to work and activity based on surgeon perception seems to match previously described outcomes.

Our study was not without limitations. Not all active orthopaedic surgeons in North America were members of COA or AOSSM, introducing the potential for selection bias. Distribution via mailing lists allowed for the selection of active staff surgeon members of COA, but we were unable to selectively distribute to active staff surgeon members of AOSSM; thus, all members were included in distribution. However, 89% of AOSSM members were surgeons (K. Boyer, AOSSM director of research, personal communication, 2020). The COA reported an approximate

membership rate of 80% (C. Vezina, chief executive officer, COA, personal communication, 2019). Active members of AOSSM were primarily American (93%), but there was potential for selection bias, as not all of American surgeons were members of AOSSM. In addition, COA members represented all subspecialties of orthopaedics, whereas AOSSM was limited to those with interest or subspecialty training in sports medicine. We did not collect personal data from respondents and, as such, could not track if a single respondent completed the survey more than once. Another limitation of this study was the response rate: 136 Canadian and 128 Americans completed the survey; thus, there was potential for selection bias. Web surveys have a potential for high nonresponse rates, which can lead to estimation error.[1] Lack of response may have been due to a lack of desire to participate in an online survey, a lack of interest in the subject matter, or a simple lack of involvement in the care of orthopaedic trauma or acute QTR. The low response rate may have affected the generalizability of our results, especially in comparison with other populations. These 2 orthopaedic associations had individual guidelines for survey distribution, amounting to 3 versus 2 email invitations, respectively. This may have contributed to differences in response rate as well. A larger number of surveys distributed by AOSSM versus COA may have also led to survey response fatigue, thereby decreasing the response rate.

We did not assess complication rates in our survey. In a systematic review, Ciriello et al[6] reported a combined 2% rerupture rate; Serino et al[30] described a 10% reoperation rate for extensor mechanism ruptures but did not break this down further. A large proportion (44.7%) of North American respondents have dealt with revision surgery for a reruptured QTR. Unfortunately, we do not have information about whether these were their own cases or were referred for revision from another surgeon. Given the high proportion of respondents conducting a revision, despite the low incidence in the literature, it is possible that (1) there was a selection bias in our respondents to those with expertise such that they would accept referrals for reruptures or (2) the rerupture rate may be higher than that quoted in the literature.

As this was a self-report study and not an observational study, results are based on surgeons' preferences rather than exact treatment decisions made in clinical practice; therefore, they are not confirmed. In addition, the details were subject to recall bias—for example, those regarding patient outcome and satisfaction, clinical volumes, and complications.

CONCLUSION

We presented data from the largest orthopaedic association in Canada, as well as one of the most prominent sports orthopaedic associations in America. Our study revealed that the TO surgical technique was the most commonly utilized and that ROM was generally advanced in a stepwise fashion of 2-week intervals of 30°. We found several differences in practice between Canadian and American respondents, including the type of preoperative imaging and the frequency of SA use. As surgical trends differ geographically or change over time, there is a need for larger-scale prospective studies to assess and compare these preferred treatment methods and rehabilitation protocols.

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