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Quality and Variability of Physical Therapy Protocols Varies Widely for Osteochondral Allograft Transplantation of the Femoral Condyles

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Abstract

Objective. To assess the quality and variability of osteochondral allograft (OCA) transplantation rehabilitation protocols associated with academic orthopedic programs in the United States. *Design.* A systematic review was performed to collect all publicly available online rehabilitation protocols for femoral condyle OCA transplant from US academic orthopedic programs participating in the Electronic Residency Application Service. These protocols were evaluated for inclusion of different rehabilitation components as well as timing of suggested initiation of these activities. *Results.* A total of 22 protocols were included. Although 91% of protocols recommended bracing, wide variation exists in total time of utilization. Median time for full weight bearing (FWB) was 7 weeks (range 4-8). On average, each protocol mentioned 9 (range 2-18) different strengthening exercises. The median time suggested to return to high-impact activities was 9 months (range 8-12). Only 3 protocols (14%) offered criteria of advancement for each phase as well as criteria for discharge. *Conclusion.* Very few of the academic orthopedic programs have published online rehabilitation protocols following OCA transplantation. Although there is wide variation between the protocols, it allowed the identification of trends or patterns that are more common. However, there is need for more standardized evidence-based rehabilitation protocols which are easy to understand and follow by patients.

Keywords

cartilage, OCA, osteochondral allograft transplantation, postoperative rehabilitation, knee

Introduction

Osteochondral allograft (OCA) transplantation is indicated to manage large (>2 cm^2) articular cartilage defects. OCA transplantation carries multiple advantages as a single-stage technique (typically following staging arthroscopy), namely utilizing viable hyaline cartilage, avoiding donor site morbidity, resurfacing large defects, and matching the native recipient surface anatomy.[1-5] In recent years, the use of OCA transplantation has significantly increased[6-8] with promising improvements in patient-reported outcomes and survival rates. In a systematic review of clinical outcomes following OCA transplant, De Caro *et al.*[5] demonstrated an 89% rate of successful return to play (RTP) and graft survivorship at 5 years. Many other clinical studies on OCA transplant outcomes have reproduced these findings, demonstrating significant pain relief and ability to return to activities of daily living postoperatively.[3,9-11] A successful outcome following OCA transplantation is not only predicated on important technical aspects of the procedure, but also adherence to a comprehensive rehabilitation protocol. Despite this surge in OCA utilization, evidence-based guidelines for postoperative rehabilitation protocols are lacking.

Optimal postoperative rehabilitation following OCA transplant requires an understanding of the principles underlying OCA incorporation. In the acute postoperative

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period, graft mechanical support is primarily derived from the press-fit fixation achieved during surgery.[9] Multiple *in vitro* and *in vivo* animal model studies have demonstrated that the first 2 weeks following OCA transplantation are the most critical for remodeling and successful bone healing.[12,13] Accordingly, strict maintenance of graft stability is essential as even small shifts in fixation or shearing forces across the graft-native knee interface may disrupt graft incorporation, microvascular blood supply, and articular surface congruency prior to bone ingrowth.[12] In addition, disruption of graft stability during early healing leads to fibrocartilage growth at the interface which can lead to graft failure.[14] After graft incorporation has been achieved, progression of weight bearing may be initiated.

Unfortunately, the effect of specific rehabilitation interventions following OCA transplantation including weight bearing, range of motion (ROM; continuous, restrictive, or intermittent active), and return to sport guidelines have not been well-studied owing to the lack of evidence-based guidelines on the topic. In a recently performed systematic review of postoperative protocols following articular cartilage repair/restoration, Hurley *et al.*[21] demonstrated that there was significant variability in recommendations for weight bearing, ROM, and return to sport protocols following OCA transplantation. Moreover, the frequency with which specific postoperative OCA transplantation protocols are utilized in practice is unknown. While the contents and quality of publicly available postoperative rehabilitation protocols have been studied for other procedures, such as arthroscopic meniscus repair and medial patellofemoral ligament (MPFL) reconstruction, no such study has been performed for OCA transplantation.[15,16]

The purpose of this study was to assess the contents and variability of publicly available OCA transplantation rehabilitation protocols associated with academic orthopedic surgery programs in the United States. Given the absence of evidence-based guidelines, we hypothesized that there would be significant variability regarding quality and contents in postoperative protocols which may limit the ability to compare clinical outcomes across institutions.

Methods

A systematic review of postoperative rehabilitation protocols following OCA transplantation of femoral condyle lesions from US academic orthopedic surgery programs was performed. A list of programs participating in the 2020 orthopedic surgery residency match was obtained from the Electronic Residency Application Service (ERAS) website to identify all programs. Two study authors (I.G-M. and M.T.) conducted independent Internet searches to obtain any and all publicly available OCA transplant rehabilitation protocols from surgeons within these programs. The following search protocol was performed for each program with the following 4 steps: (1) the program's website was identified and searched for OCA transplant postoperative rehabilitation protocols within the orthopedic surgery and physical therapy department websites; (2) a Google search engine query was performed to identify OCA transplant protocols affiliated with the program; (3) the name of each orthopedic sports surgeon affiliated with the institution plus the phrases "Osteochondral Allograft Transplant rehabilitation protocol" and keywords "post-operative patient instructions," "rehabilitation," "therapy," "knee," and "cartilage" were searched; (4) a Google query was performed using the same aforementioned keywords without institution-specific criteria, in the chance that we would find protocols from surgeons missed in our original search. Inclusion criteria for postoperative OCA transplantation protocols were as follows: (1) treatment of isolated femoral condyle lesions and (2) protocols from orthopedic surgery academic institutions and their affiliate sports surgeons. Exclusion criteria were as follows: (1) non-ERAS programs, (2) postoperative protocols other than OCA transplantation for isolated femoral condyle lesion (protocols for patellofemoral lesions and/or concomitant surgeries including but not limited to femoral/tibial osteotomy and meniscal transplantation were excluded), (3) protocols lacking specific instructions or rehabilitation guidelines.

Protocols that met inclusion criteria were reviewed by 3 study authors (I.G-M., M.T., and A.S.). Any discrepancies between reviewing authors were identified, discussed, and jointly judged to achieve consensus. All rehabilitation components in each protocol were recorded and grouped into one of the following 7 categories: (1) prehabilitation and postoperative adjunct therapy, (2) bracing, (3) ROM and continuous passive motion (CPM) device, (4) weight bearing, (5) strengthening, (6) return to activities and sports, and (7) goals and criteria of advancement. Each protocol was then assessed for the presence or absence of these rehabilitation components as well as on the suggested points in the recovery process at which these components are recommended. For each rehabilitation activity, the proportion of protocols that included the component was calculated. In addition, the time of initiation (median and range) for each component was determined across the included protocols.

Results

A total of 178 US academic orthopedic surgery programs were identified. The search process is shown in **Figure 1**. A total of 22 protocols were included in the analysis. **Table 1** shows a summary list of key rehabilitation components based on the most common recommendations among the 22 protocols studied.

Prehabilitation and Postoperative Adjunct Therapy

None of the 22 protocols included preoperative therapy ("prehabilitation") instructions. The prevalence of specific

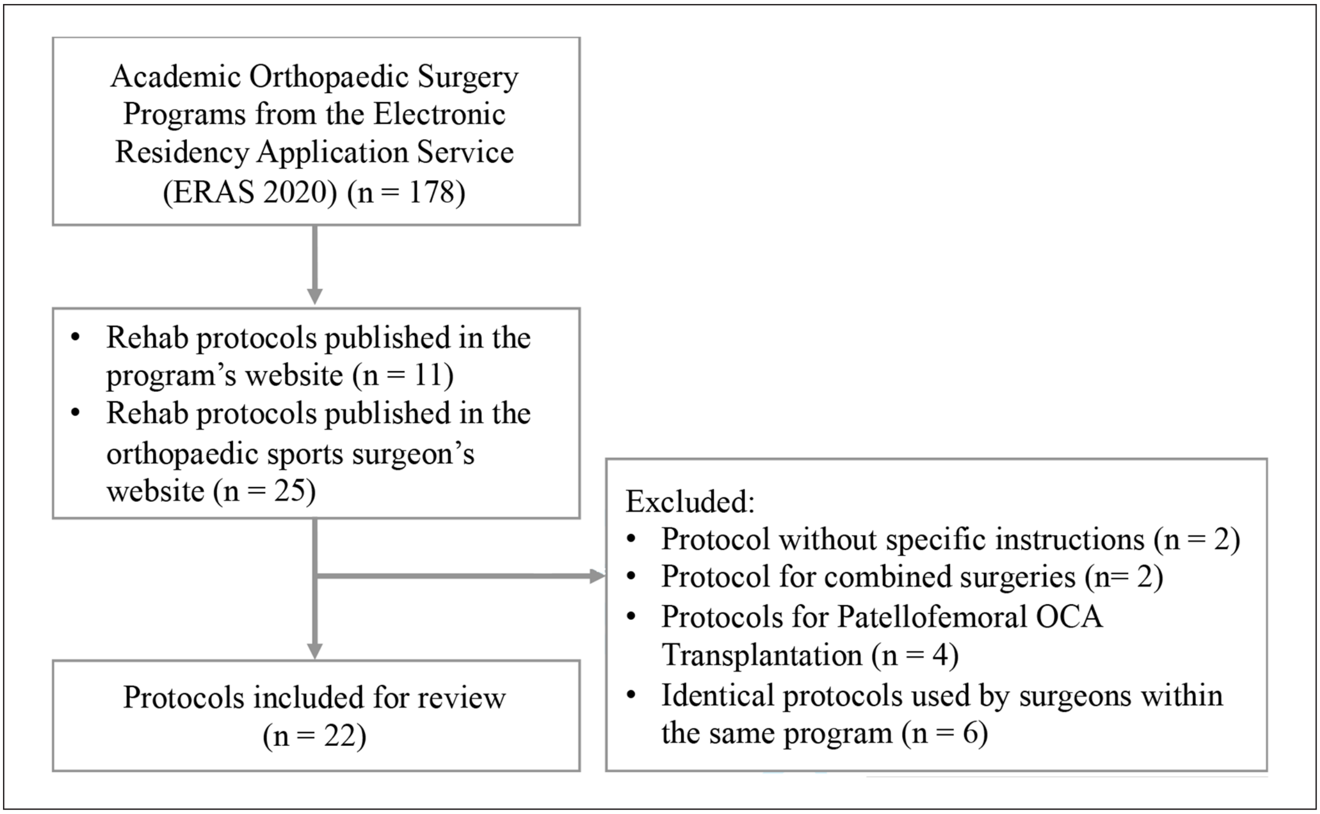

Figure 1. Search process flowchart. OCA = osteochondral allograft.

Table 1. Summary List of Key Rehabilitation Components Based on the Most Common Recommendations Among the 22 Protocols Studied.

Brace	Brace is typically recommended for 6 weeks (locked in full extension for the first week)
Rage of motion	ROM is generally initiated with CPM for 6 weeks (6 hours a day, starting at 40° and progressions of 5°-10° per day) achieving full ROM at 6 weeks.
Weightbearing	Postoperative TTWB for 6 weeks, followed by PWB 2 weeks, achieving FWB at 8 weeks.

ROM = range of motion; CPM = continuous passive motion; TTWB = toe-touch weight bearing; PWB = partial weight bearing; FWB = full weight bearing.

postoperative therapy components across protocols is summarized in **Figure 2**. The majority of protocols recommended bracing (n = 20, 91%), CPM (n = 18, 82%), and patellar mobilization (n = 14, 64%). Other recommended therapy components included icing (n = 8, 36%), elevation (n = 6, 27%), tibiofibular joint mobilization (n = 3, 14%), massage (n = 2, 9%), towel roll (n = 2, 9%), and compression (n = 1, 4.5%).

Bracing

In all, 20 of 22 (91%) protocols recommended bracing postoperatively. The recommended total time of brace utilization and total time of brace locked in extension are summarized in **Figure 3**. Six protocols (30%) recommended brace use for a total of 6 weeks, with the brace locked in full extension for the first week followed by the addition of 20° of flexion for each week thereafter. Four protocols (20%) indicated a brace but did not explain how it should be used or how much time. Finally, 6 protocols (30%) mentioned parameters to discontinue brace use, which were the quadriceps control and single leg raise (SLR) without extension lag.

ROM and CPM

Eighteen protocols (82%) recommended the use of CPM therapy postoperatively. Of these, 16 (89%) protocols included specific guidelines for CPM settings for number of

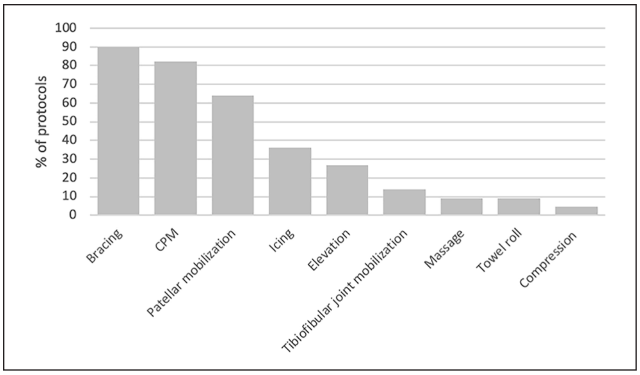

Figure 2. Osteochondral allograft transplantation postoperative therapies. Data are shown in percentage of protocols prescribing each type of therapy. CPM = continuous passive motion.

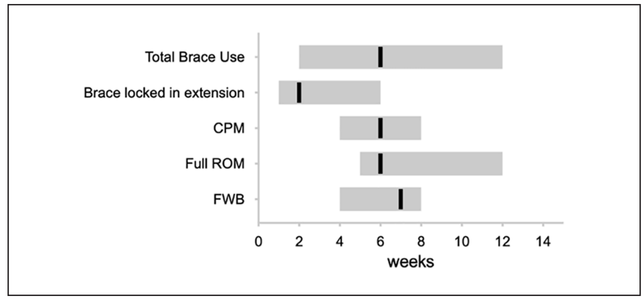

Figure 3. Timing for brace, CPM, range of motion, and weightbearing following osteochondral allograft transplantation. Medians are shown as vertical black lines and ranges as gray bars. CPM = continuous passive motion; ROM = range of motion; FWB = full weight bearing.

hours per day of use, ROM progression, and timing to full ROM. The median time of utilization was 6 weeks (range 4-8) (**Fig. 3**). Median hours a day of use was 6 hours (range 3-8) and median starting degrees of flexion was 40° (range 30-90). Most common progression rate was 5° to 10° per day (n = 7, 44%). Full ROM achievement time varied widely between protocols, median was 6 weeks (range 5-12) (**Fig. 3**). Three protocols did not mention ROM guidelines at all.

Weightbearing

Almost all protocols addressed weightbearing (n = 20, 91%). Of these, more than half protocols (n = 13, 65%) recommended postoperative toe-touch weight bearing (TTWB) while 7 (35%) non-weight bearing (NWB). Median time for full weightbearing (FWB) was 7 weeks (range 4-8) (**Fig. 3**). The most frequently utilized recommendation (35%) was 6 weeks of TTWB, followed by 2 weeks of partial weight bearing (PWB) with 25% increase weekly, achieving FWB at 8 weeks.

Strengthening

A total of 30 different exercises were recommended across all protocols. On average, each protocol mentioned 9 (range 2-18) different strengthening exercises. Passive leg hangs to 90° at home (n = 8, 36%), Quadriceps/Hamstrings/Gluteus sets (n = 16, 73%), SLR, and ankle pumps (n = 8, 36%) were recommended to start the first postoperative week in all the cases. The most common utilized exercises recommended later in the postoperative course are shown in **Figure 4**.

Return to Activities and Sports

Almost 80% of protocols (n = 17) mentioned return to basic activities and sports. The most common recommended

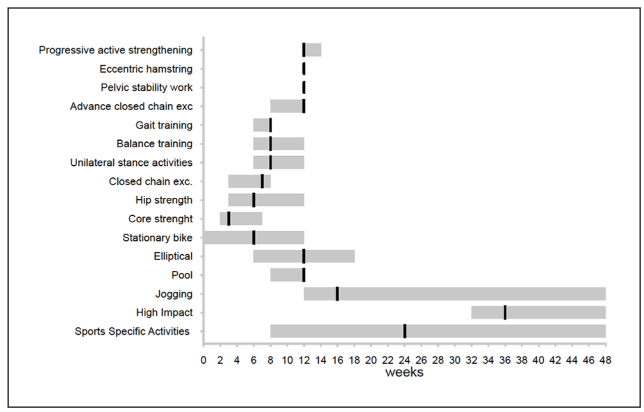

Figure 4. Initiation time points of the most commonly indicated strengthening exercises and return to different activities following osteochondral allograft transplantation. Medians are shown as vertical black lines and ranges as gray bars.

activity was stationary bike (n = 17, 77%) at a median of 6 (range 0-12) weeks. Other activities addressed in the protocols were elliptical (n = 10, 45%), pool (n = 8, 36%), jogging (n = 9, 41%), generic "sport-specific" activities (n = 10, 45%), and high-impact activities (n = 10, 45%) (**Fig. 4**).

Goals and Criteria of Advancement

Six protocols (27%) included goals and precautions for each phase of the rehabilitation process, whereas 2 included goals regarding ROM only. Three protocols (14%) offered criteria of advancement for each phase as well as criteria for discharge.

Discussion

This systematic review is the first to assess the availability, variability, and components of postoperative protocols following OCA transplantation from US academic orthopedic surgery institutions. Overall, there is a dearth of publicly available information on rehabilitation following OCA transplantation with only 22 of 178 (12.3%) of academic orthopedic surgery programs providing postoperative therapy guidelines and timing for patients undergoing this procedure. The results of this study confirmed our hypothesis; among the available online protocols, there was wide variation in the specific components of recommended postoperative adjunctive therapy, ROM, weightbearing, and return to sport guidelines.

The low rate of OCA transplantation postoperative therapy protocol availability (12.3%) reported in the present study is comparable with those reported in similar recent systematic reviews assessing online postoperative rehabilitation protocols following other surgical procedures including anterior cruciate ligament (ACL) reconstruction, MPFL reconstruction, and arthroscopic meniscus repair.[15-18] Evaluating ACL reconstruction postoperative protocols, Makhni *et al.*[17] reported that 33 (21%) out of 155 ERAS programs published physical therapy protocols online. Postoperative protocol availability for MPFL reconstruction and arthroscopic meniscus repair were 17% and 13% to 15%, respectively, as reported by Lieber *et al.*,[16] DeFroda *et al.*,[15] and Trofa *et al.*[18]

Unlike recommended rehabilitation protocols for many other knee surgeries, our results demonstrated that none of the 22 therapy protocols for OCA transplantation recommended therapy preoperatively ("prehabilitation"). In contrast, Makhni *et al.*[17] reported that 31% of available ACL reconstruction rehabilitation protocols recommended prehabilitation exercises including ROM and quadriceps strengthening. However, in a study of variability of rehab protocols, after MPFL reconstruction none of the protocols mentioned prehabilitation.[16] Similarly, preoperative therapy is routinely recommended for patients undergoing other cartilage repair procedures and total knee arthroplasty.[17-19] In particular, Hirschmüller *et al.*[20] have recently published a prehabilitation protocol specifically designed for cartilage repair procedures to improve preoperative quadriceps strength, neuromuscular control, and general fitness and demonstrated excellent compliance among a 50 patient cohort. Unfortunately, there is a paucity of studies evaluating the impact of a preoperative therapy program on clinical outcomes following OCA transplantation, which likely contributes to the absence of this component in the protocols assessed in the present study.

Our results demonstrated that there was a high degree of variability among available protocols regarding recommendations for bracing and ROM following OCA transplantation. The most frequently recommended duration of brace use was 6 weeks ($n = 6$, 30%), but this ranged widely from 2 to 12 weeks. Almost all ($n = 20$, 91%) protocols recommended maintaining the brace in full extension postoperatively. The most frequently recommended duration for extension bracing was 2 weeks, but this also ranged widely from 1 to 6 weeks. Protocols also varied in the recommended target goal for achieving full ROM, with 6 weeks being the most frequent goal (range 5-12). In contrast to these protocols, a systematic review of 52 studies reporting clinical outcomes following OCA transplantation, 80% of reporting surgeons allowed ROM 1 week postoperatively.[21] In addition, a recently published OCA transplant postoperative therapy protocol by Haber *et al.* recommended immediate knee ROM after OCA, both active and passive, with emphasis on achieving full extension as soon as possible.[22]

Basic science studies have suggested a role of CPM following knee cartilage surgery; however, it has not been translated to the clinical studies.[23-25] The use of CPM has fallen out of favor of ACL reconstruction in light of multiple clinical outcome studies demonstrating no substantial benefit.[26] In contrast, it was notable that most of the protocols found in our search recommended the use of CPM for ROM (82%). Given the paucity of clinical studies, the impact of CPM on outcomes following OCA transplantation remains unknown. Finally, patient access to CPM therapy may be limited as the adjunctive therapy is typically not covered by most insurers.

As with other protocol components, the results of our study demonstrated high variability among postoperative weightbearing recommendations following OCA transplantation. The most frequent postoperative weight bearing regimen recommendation was TTWB (65%), followed by NWB (35%). The majority of protocols advanced patients to full weight bearing by 8 weeks (45%) while this ranged from 4 to 8. This high variability in postoperative weight bearing recommendations is consistent with the results of a recent survey of practicing surgeons assessing postoperative protocols following OCA transplantation. In that study, Kane *et al.*[27] demonstrated that postoperative regimens ranged from immediate weightbearing as tolerated (WBAT) to NWB for 12 weeks. In addition, high-volume surgeons (performing 20 OCA transplantations per year) tended to be more aggressive with initiation of weight bearing than lower-volume surgeons (fewer than 10 OCA transplantations per year).[28]

Our results demonstrated highly variable recommendations in the initiation of specific activities and criteria for return to sport (discharge from therapy). The most common time for return to stationary bike was 6 weeks, jogging at 16 weeks, sports-specific activities at 24 weeks, and high-impact activities at 9 months postoperative. In a systematic review by Hurley *et al.*,[21] the average reported time of RTP after OCA transplantation was 9.4 months (range 7.9-14). Balazs *et al.*[28] reported that elite basketball players RTP at the same level at a median time of 14 months (range 6-26), with an overall RTP rate of 80%.

Home-based, patient-directed therapy has gained popularity in the postoperative management of many surgeries including ACL reconstruction.[29,30] While none of the protocols reviewed in this study specified the setting of treatment (home or office), this is an important consideration as cost-effectiveness, convenience, and Covid-19 restrictions may play a significant role in patient and hospital system preference. In our study, most protocols were not detailed enough and lacked specific instructions on how to perform each exercise for the patient to understand and follow the instructions themselves. We believe this impedes the patient from independent physical therapy and makes them more dependent on professional physical therapy.

Quadriceps atrophy is one of the main complications of the knee surgery and has been reported frequently after ACL surgery. It is reported that only 29% of patients achieve limb symmetry less than 10% when the injured limb was compared with preinjury limb values at 6 months after ACL reconstruction.[31] Similar to the ACL, focusing on quad atrophy is also an important part of rehabilitation after OCA. Voluntary strengthening alone can be sometimes insufficient and in that case electric stimulation or blood flow restriction training with low loads can help recover the muscle strength, particularly in patients who experience pain on exercise and those with load compromise.[32]

There are several limitations of this study. First, our search was confined to the publicly available OCA transplantation rehabilitation protocols from academic orthopedic surgery programs participating in ERAS. Consequently, this review likely represents a minority of available OCA transplantation rehabilitation protocols as non-ERAS protocols were not searched nor were protocols with private access. However, this methodology was employed to decrease the selection bias and select the highest quality protocols. It is possible that this methodology may have introduced a systematic bias by focusing on academic programs as this might not represent the practices of surgeons not affiliated with academic institutions. Finally, it is essential to acknowledge that our methodology does not allow the efficacy of these protocols to be assessed as there is a paucity of clinical outcome data on the topic. Future studies on the impact of specific postoperative protocols on clinical outcomes following OCA transplantation will be essential to the development of high-quality clinical practice guidelines.

In summary, there are relatively few publicly available OCA transplantation rehabilitation protocols from US academic institutions. Despite increased utilization of OCA transplantation, there is substantial variability among current protocols regarding the type of activities and timing of initiation in the postoperative period. This variability makes it difficult to compare outcomes across interventions and studies. To optimize patient outcomes following OCA transplantation, further clinical research is needed to identify the most valuable rehabilitation activities and to standardize postoperative protocols accordingly with the establishment of evidence-based guidelines.

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Declaration of Conflicting Interests

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