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Early versus delayed surgery for anterior cruciate ligament reconstruction: a systematic review and meta-analysis

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Abstract There is no consensus in the literature regarding the optimal timing of surgical reconstruction of the ruptured anterior cruciate ligament (ACL). Previous authors have suggested that early reconstruction may facilitate an early return to work or sport but may increase the incidence of post-operative complications such as arthrofibrosis. This study systematically reviewed the literature to determine whether ACL reconstruction should be performed acutely following rupture. Medline, CINAHL, AMED, EMBASE databases and grey literature were reviewed with a meta-analysis of pooled mean differences where appropriate. Six papers including 370 ACL reconstructions were included. Early ACL reconstructions were considered as those undertaken within a mean of 3 weeks post-injury; delayed ACL reconstructions were those undertaken a minimum of 6 weeks post-injury. We found there was no difference in clinical outcome between patients who underwent early compared to delayed ACL reconstruction. However, this conclusion is based on the current literature which has substantial methodological limitations.

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Introduction

The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee with an incidence of 8 per 100,000 cases per year [6, 28]. Surgery is the typical treatment for younger athletes or those with physically demanding occupational or sporting pursuits since it restores stability and limits the potential for progressive degeneration and long-term instability of the knee [2, 4, 19].

Surgical techniques of ACL reconstruction have evolved over the past three decades with debate regarding timing of reconstruction [37]. In a national survey by Francis et al. [12], of 101 consultant orthopaedic surgeons in the UK, 81% reported that they considered the ideal time span from injury to operation to be between 1 and 6 months, although it was acknowledged that only 35% of ACL reconstructions are performed within this time-frame in National Health Service hospitals.

Proponents of early surgical intervention during the initial weeks post-injury have suggested that restoring tibiofemoral stability may minimise the risk of further meniscal and chondral injury which may be associated with degenerative joint changes [3, 9, 35]. Early surgery may also facilitate return to sporting and occupational pursuits with considerable economic consequences. Delayed ACL reconstruction may be associated with an increase in muscle atrophy and reduced strength which may delay early rehabilitation [10, 29]. Conversely, delaying surgical intervention allows optimisation of pre-operative knee range of motion and recovery of surrounding soft tissues from the initial injury potentially reducing the incidence of post-operative arthrofibrosis and wound complications [17, 31, 37, 38].

There is no consensus in the current literature regarding the optimal time of surgical intervention [29]. The purpose of this study was to assess the effects of duration from injury to surgical intervention for patients undergoing ACL reconstruction by comparing the clinical and radiological outcomes of early to delayed ACL reconstruction following initial injury.

Patients and methods

Data sources and searches

A database search was performed via Ovid of Medline (1950 to June 2009), CINAHL (1982 to June 2009), AMED (1985 to June 2009) and EMBASE (1974 to June 2009) using MeSH terms to identify all English-language randomised and non-randomised clinical trials specifically comparing outcomes of early versus delayed ACL reconstructions. The key word terms and Boolean operators used were "anterior cruciate ligament reconstruction" AND "surgery" AND "timing" OR "delay." We also searched for unpublished literature using the search term "anterior cruciate ligament" from the databases SIGLE (System for Information on Grey Literature in Europe), the National Technical Information Service, the National Research Register (UK) and Current Controlled Trials databases. We attempted to contact the corresponding authors of each included paper to highlight any omitted citations. Trials were included irrespective of whether the surgery was open or arthroscopic, the type of graft, gender or post-operative rehabilitation. The reference lists of review papers were scrutinised for relevant publications not identified by the initial search strategy. Single case reports, comments, letters, editorials, protocols, guidelines and review papers were excluded. We also excluded studies evaluating cases under the age of 16; studies of revision ACL reconstruction; studies presenting result of ACL repair rather than reconstruction; and papers which did not specifically detail the range of time between injury and surgery for their acute and delayed groups. Two investigators (TS, LD) independently selected articles meeting the inclusion criteria.

Data extraction and quality assessment

Two investigators (TS, LD), blinded to the source, publication date, authors and affiliations for each paper, used a standardised extraction form. All papers were then evaluated against the eleven-item PEDro scoring system by TS and LD independently. The PEDro appraisal tool has demonstrated reliability and validity in the assessment of randomised controlled trials [11, 24]. Disagreements regarding study selection, data extraction or appraisal score were resolved through discussion.

Statistical analysis

A meta-analysis was conducted by one investigator (TS), using REVMAN software (version 5.0 for Windows. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008). For the purposes of analysis, early ACL reconstruction patients were considered as those procedures undertaken within a mean of 3 weeks post-injury. Delayed ACL reconstruction patients were considered as those patients whose operations were undertaken after 6 weeks from injury. Where there was no substantial evidence of a difference in study populations, interventions or outcome measurements, a meta-analysis was employed. Mean pooled difference was assessed for continuous data, and pooled relative risk ratios for dichotomous data. A probability of $P < 0.05$ was determined as statistically significant, whilst 95% confidence intervals were calculated. We assessed heterogeneity by χ^2 and I^2 statistical tests. Where statistical heterogeneity measured using I^2 was less than 10%, a fixed odds ratio was used, for outcomes above 10%, a random effects model was used. Where insufficient data was presented in publications, attempts were made to contact corresponding authors.

A funnel plot was generated to inspect for publication bias for the outcome measures most frequently presented by the papers reviewed.

Results

A total of 254 citations were identified from the search strategy and six studies were deemed appropriate (Fig. 1). Two papers were excluded because it was unclear what the mean time from injury to operation was [15, 21]. Two further papers were excluded as they categorised early ACL reconstructions as those procedures undertaken within 12 months post-injury [5, 29]. Seven papers were excluded as they assess surgical intervention later than 3 weeks in the early intervention group, or less than 6 weeks in the delayed surgery group [7, 16, 18, 25, 36, 38, 39].

Publication bias was assessed using a funnel plot of the incidence of meniscal damage (Fig. 2). This suggested that publication had little impact on the outcomes of this meta-analysis.

In total, 161 ACL reconstruction procedures termed as early were compared to 209 delayed procedures. The mean age was 25.6 years in the early group [Standard deviation (SD) = 2.3] compared to 26.2 years (SD = 1.1) in the delayed group (Table 1).

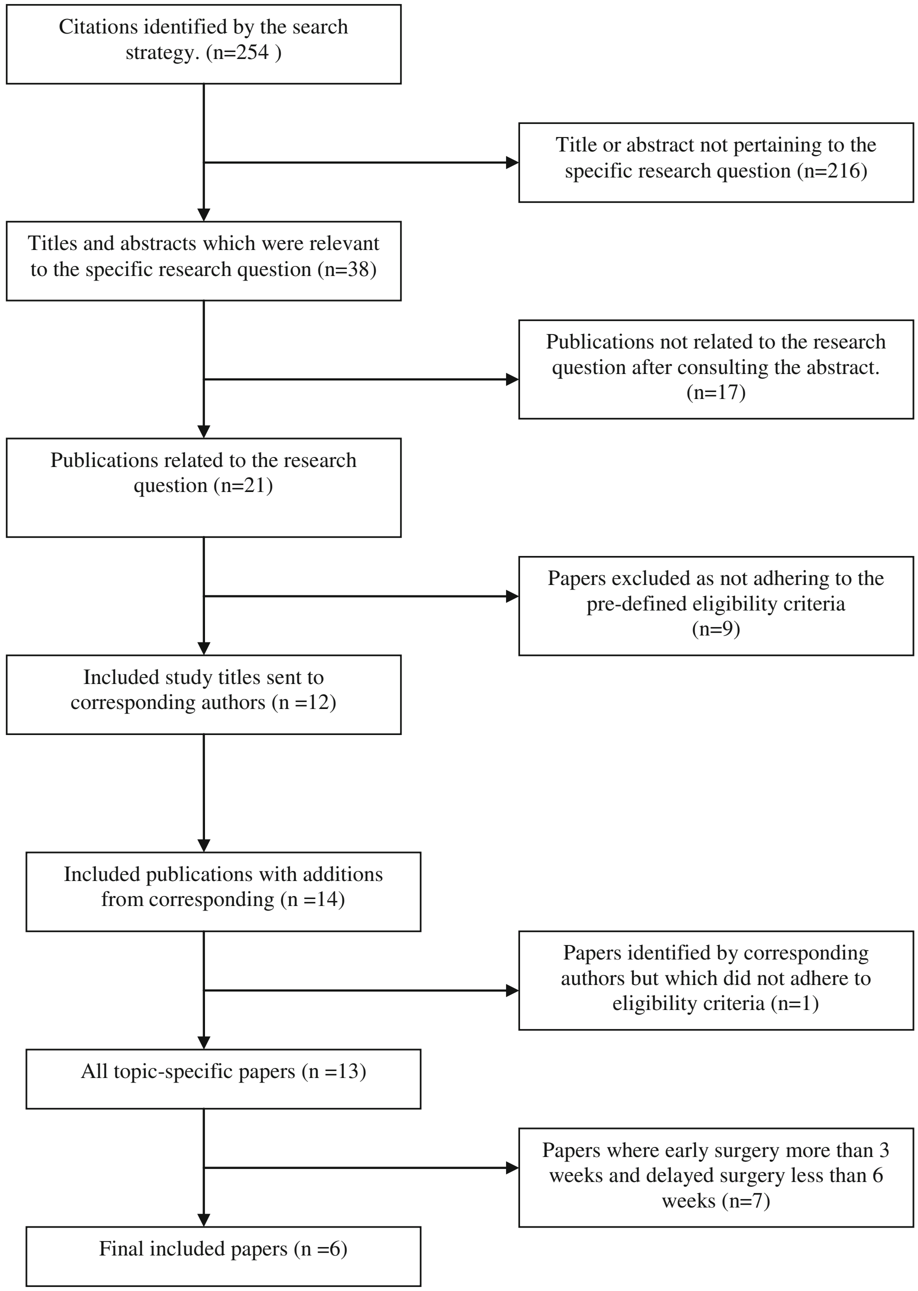

Fig. 1 A QUORUM chart

There was no statistically significant difference between the early and delayed ACL reconstruction groups for the Lysholm score or Tegner score (Table 2). There was no significant difference between the groups for International Knee Documentation Committee rating score [not significant (n.s.)] [26], IKDC perceived stability rating (n.s.) [26], or the Hospital for Special Surgery score system (n.s.) [35]. There was no reported significant difference in patient satisfaction ($P = 0.19$) [35]. The frequency that patients returned to the same level of sporting participation was assessed in Marcacci et al.'s [26] paper. This reported that there was no statistically significant difference in return rates between the two groups (n.s.) [26].

Tibiofemoral laxity was assessed using a variety of outcomes including KT-1000 arthrometer measurements, assessment of Lachman and the pivot shift tests. There was no statistically significant difference between the groups for any measurement of tibiofemoral laxity or instability (n.s.; Table 2). The literature assessed knee range of motion using a variety of different methods. These included the assessment of extension or flexion deficit measurements [4, 35] and by the frequency of an extension deficit of greater than 10° [4, 26, 34] There was no significant difference in these range of motion measurements between those who underwent early compared to delayed ACL reconstruction (n.s.; Table 2).

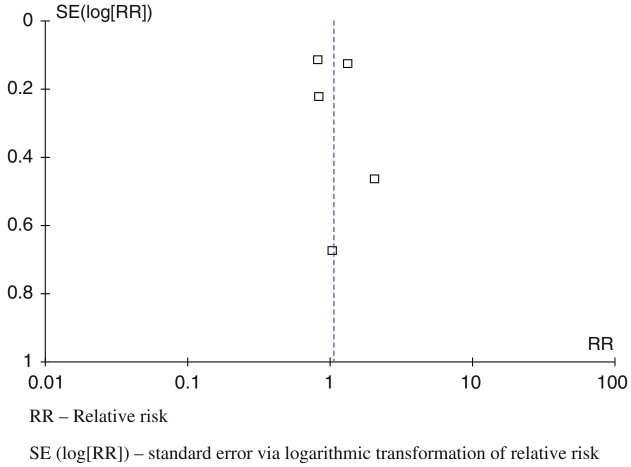

Fig. 2 Funnel plot to assess publication bias of the studies measuring the incidence of meniscal damage

The incidence of arthrofibrosis, chondral injuries, patellofemoral pain or meniscal injuries was calculated. No statistically significant difference was seen for these outcomes (n.s.; Table 2). There was no significant difference between early and delayed surgery in respect to patellofemoral joint crepitus in the one study which assessed this outcome (n.s.) [26]. Similarly, there was no significant difference in thromboembolic complications or the frequency of revision surgery between the groups on meta-analysis (n.s.; Table 2).

There was considerable heterogeneity between studies in assessment of isokinetic strength. Meta-analysis was therefore inappropriate and a narrative assessment was performed. Nonetheless, on narrative review, Petersen and Laprell [34] and Wasilewski et al. [42] reported that there was no significant difference between the groups for isokinetic muscle strength assessed using dynamometry (n.s.) or quadriceps and hamstring torque (n.s.) in their studies, respectively.

Critical appraisal

The findings of the PEDro review suggested that the literature had a number of methodological limitations. As Table 3 illustrates, although the evidence-base largely identified where their population was recruited from and the eligibility criteria, only two papers were randomised. Similarly, an assessment of group differences at baseline was only documented in two studies. Although it would have been impossible to blind subjects as to whether they underwent early or delayed surgical interventions, no paper blinded the surgeon as to whether the patient was about to have an early or delayed ACL reconstruction. Whilst blinding the surgeon would be ethically and logistically difficult, the studies reviewed rarely blinded their assessors to whether subjects had early or delayed reconstruction, which would have been easier to undertake. Unfortunately, the literature assessed poorly the precision of their results using confidence intervals or variance in descriptive statistics using standard deviation values, a further limitation to the evidence. Although not assessed by the PEDro scale, no study based its sample size on a power calculation.

Discussion

The most important finding of the present study was that there is no statistically significant difference in outcomes between those patients who underwent earlier compared to delayed ACL reconstruction (n.s.). Unfortunately, the literature had a number of methodological limitations including poorly randomising samples to group allocation; rarely blinding assessors or surgeons to group allocation; limited use of interferential statistics and confidence intervals; and not justifying sample sizes on power calculations, permitting type II statistical error to occur. Accordingly, the conclusions made in this review should be interpreted with caution.

The degree of injury to the knee, rather than time from injury, has been suggested as the most important factor when considering when to reconstruct the ACL [1, 33, 38]. Mayr et al. [27] retrospectively reviewed a cohort of 156 patients with post-operative arthrofibrosis following ACL reconstruction. They identified that knee irritation, effusion

Table 1 Demographic characteristics

Paper (date)	Mean time from injury to surgery		Knees		Age		Graft type	Follow-up (months)
	Early	Delay	Early	Delay	Early	Delay		
Bottoni et al. [4]	9 days	85 days	35	35	26.4 (SD 6.8)	27.5 (SD 6.0)	Hamst	12
Marcacci et al. [26]	<15 days	11 months	23	59	24 (15–36)	26 (14–38)	BP-TB	60
Meighan et al. [28]	<2 weeks	8–12 weeks	13	18	n/s	n/s	Hamst	12
Petersen and Laprell [34]	<3 weeks	>10 weeks	27	37	28.5	26.3	BP-TB	22
Sgaglione et al. [35]	9.6 days	22.5 months	22	28	23.4 (SD 7.6)	24.8 (SD 6.6)	Hamst	37
Wasilewski et al. [42]	0–1 months	>6 months	41	32	n/s	n/s	Hamst	18

BP-TB Bone Patella-Tendon Bone graft, *Hamst* Hamstring tendon graft, *n/s* not stated, *SD* standard deviation

Table 2 Results of meta-analysis

Outcome	Papers	Relative risk (95% CI)	Overall effect (P value)	Heterogeneity	
				χ^2	I^2
Lysholm Score	[4, 34, 35]	0.07 (−9.93, 10.08)*	0.99	0.02	81
Lysholm Score (Good/excellent)	[26]				
Tegner Score	[4, 34, 35]	−0.07 (−0.42, 0.29)*	0.71	0.60	0
KT-1000 Arthrometer	[4, 34, 35]	0.05 (−0.52, 0.63)*	0.85	0.19	42
Tibiofemoral Displacement > 3 mm	[25, 35]	0.59 (0.25, 1.43)	0.24	0.19	43
Positive Lachman	[26, 34, 35]	0.64 (0.27, 1.51)	0.31	0.02	73
Positive pivot shift	[26, 34, 35]	0.69 (0.43, 1.11)	0.13	0.52	0
Extension deficit	[4, 35]	−0.90 (−2.39, 0.59)*	0.24	N/E	N/E
Flexion deficit	[4, 35]	−0.50 (−2.55, 1.55)*	0.63	N/E	N/E
Extension deficit > 10°	[4, 26, 34]	0.96 (0.21, 4.37)	0.96	0.21	36
Incidence of arthrofibrosis	[28, 34, 35, 42]	1.83 (0.81, 4.14)	0.15	0.76	0
Incidence of meniscal injury	[4, 26, 28, 34, 42]	0.92 (0.71, 1.19)	0.53	<0.01	74
Incidence of chondral injury	[4, 26, 34, 42]	0.77 (0.44, 1.37)	0.38	0.26	25
Frequency of revision surgery	[26, 28, 34, 35, 42]	0.81 (0.42, 1.58)	0.54	0.30	17
Incidence of patellofemoral pain	[35, 42]	2.05 (0.86, 4.89)	0.11	0.58	0
Incidence of thromboembolic complication	[28, 35]	1.79 (0.21, 27.29)	0.68	0.21	37

* Mean difference (95% confidence intervals), ° degrees, *CI* confidence intervals, *mm* millimetres, N/E not estimated

Table 3 PEDro critical appraisal results

	Bottoni et al. [4]	Marcacci et al. [26]	Meighan et al. [28]	Petersen and Laprell [34]	Sgaglione et al. [35]	Wasilewski et al. [42]
Eligibility criteria	1	0	1	0	1	0
Random allocation	1	0	1	0	0	0
Concealed allocation	1	0	0	0	0	0
Baseline comparability	1	0	0	0	0	1
Blind subject	0	0	0	0	0	0
Blind clinician	0	0	0	0	0	0
Blind assessor	0	0	1	0	0	0
Adequate follow-up	1	1	1	0	1	1
Intention-to treat analysis	0	0	1	0	0	0
Between-group analysis	1	1	1	1	1	1
Point estimates and variability	1	0	0	1	1	0
Total score	7	2	6	2	4	3

1 one point, 0 no point

and swelling were highly significant when correlated with the development of arthrofibrosis ($P < 0.001$) [27]. This was in agreement with Cosgarea et al. [7] who reported that the motion deficits in acute knee injuries may be related to the normal inflammatory responses occurring as a result of knee injury. They suggested that arthrofibrosis was significantly more likely in patients with a pre-operative motion deficit of 10° or greater compared to those without [7]. Similarly, Shelbourne and Patel [37] suggested that pre-operative hyperextension is essential to allow the ACL graft to fit and incorporate within the intercondylar notch without causing impedance to extension from haematoma formation or effusion. They further suggested that this response may vary between patients and those with a minimal inflammatory response and near normal knee motion may be suitable candidates for an ACL reconstruction within the first 2 weeks [37]. Conversely, if an inflammatory response has not subsided at 3 weeks, then further delaying surgical intervention would be recommended, and the continuation of physiotherapy is recommended to regain range of motion as soon as possible. This portrays current surgical opinion reflected in a survey of

993 American Orthopaedic Society for Sports Medicine members which demonstrated that knee range of motion and the presence of knee effusion were regarded as the most important factors in deciding when to perform an ACL reconstruction [8]. The findings of our meta-analysis would refute this suggestion since early ACL reconstructions were not shown to significantly increase the risks of arthrofibrosis formation. However, since the majority of studies did not stipulate the pre-operative range of motion, degree of effusion or inflammation, it remains unclear whether these factors were important in the studies reviewed which had compared two similar groups, rather than retrospectively analysing problematic patient groups.

Hunter et al. [16] commented that the early literature cited that early reconstruction increased the incidence of arthrofibrosis and knee stiffness compared to later studies, through the development of modern arthroscopic techniques. Wasilewski et al. [42] also noted the reduction in complications associated with arthroscopically compared to open ACL reconstruction, supported by other studies assessing surgical technique [8]. Although there has been a long-held view that timing of surgery may be an important factor in the success of an ACL reconstruction, as this review suggests, such a notion may now not necessarily be supported by the literature through the evolution of surgical and rehabilitation strategies.

There was considerable variation in the post-operative strategies and physiotherapy management between the studies reviewed. This is a major limitation as Shelbourne et al. [38] cited that the post-operative management of this patient group may have a significant effect on the incidence of arthrofibrosis. Shelbourne et al. [38] reported that the use of an accelerated rehabilitation programme completely eliminated significant arthrofibrosis in those patients who had surgery 7–21 days post-injury. As a result, the majority of studies published from the mid-1990s onwards adopted a similar accelerated rehabilitation programme. This may have accounted for the differences in conclusions drawn from those studies published before this period.

There was no significant difference in quadriceps power with timing of ACL reconstruction in the other studies (n.s.). Deficits in quadriceps power have been previously cited as persisting at 1-year post-ACL reconstruction [14]. This factor is regarded as important in the long-term success of patients returning to pre-injury sporting and occupational pursuits [32]. Given the heterogeneity in strength measurements, further study using standardised dynamometry is recommended to determine whether the timing of surgery can influence motor control, and whether is variable significantly impacts upon the success of rehabilitation, and the return to pre-injury functional status.

Only Järvelä et al. [18] assessed the effects of patellofemoral and tibiofemoral joint degenerative changes between those who underwent early (mean 6 days post-injury) compared to delayed (mean 3.7 years post-injury) ACL reconstruction. They reported that whilst there was a greater incidence of medial compartment tibiofemoral changes, there was no difference between the groups for lateral compartment or patellofemoral degenerative changes. This finding agreed with Johma et al.'s [19] paper which assessed the outcomes of ACL reconstructions performed from 0 to 12 weeks post-injury compared to after 12 weeks. These authors suggested that delaying ACL reconstruction in functionally unstable knees, may result in a greater incidence of increased meniscal injury and therefore subsequent tibiofemoral joint degeneration [19]. This was attributed to the increased tibiofemoral translation of anterior cruciate ligament deficient knees accelerating the arthritic degeneration [19, 20, 40]. Previous authors have also acknowledged that the odds of a meniscal lesion significantly increase, as the time between injury to surgery increases [13, 20, 30, 41]. However, the findings of this review do not support this hypothesis where the incidence of meniscal disruption or osteoarthritic changes was not shown to be significantly different ($P > 0.05$). However, since the sample sizes were underpowered, recruiting a small number of patients, this finding may be questionable and therefore, this area remains poorly researched with further study required.

Psychologically, Shelbourne and Foulk [36] acknowledged that delaying surgery may allow the patient to prepare mentally and arrange college and work activities for their expected absence. Although patients may perceive that immediate reconstruction may be the quickest way to get back to pre-injury activity, patients may be slower to return due to possible suboptimal mental state after their injury [36]. The interval between injury and surgery may be important to proved counselling and guidance to some patients either from their surgeon, physiotherapist, coach, from friends and family or qualified sports psychologist and counsellors [38]. Further study to assess the psychological state of patients to determine if this is a factor may be of further interesting as a qualitative study methodology, to see whether this too is an important factor in the rehabilitation and timing of surgical intervention.

This systematic review has concluded that the cost-benefit analysis of permitted early rehabilitation and return to work against prolonged physiotherapy and delayed surgery has not been assessed. Further study is warranted to determine whether financial considerations are important between these two surgical strategies, to assess the effects of this variability in recreational or semi-professional sports people as well as non-sporting people. Finally, it may be argued that surgery should be delayed to assess whether a patient can be managed conservatively first. This "wait and see" approach was suggested by Bottoni et al. [4] and cited as an appropriate approach for some patients given that the literature has recommended that ACL deficit patients may function well following a formal physiotherapy programme [22, 23]. Further study may be recommended to assess the effects of this in addition to the implications such a strategy may have on an economic evaluation, to further the evidence-base in this area.

Conclusions

The findings of this study suggested that there was no statistically significant difference in outcomes between those patients who underwent earlier compared to delayed ACL reconstruction. The present evidence-base presented with substantial methodological limitations. A sufficiently powerful, well-design randomised controlled trial is required to determine whether of duration from injury to surgical intervention is an important prognostic indicator for patients who undergo an ACL reconstruction.

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