Immediate recovery room radiographs after primary total knee arthroplasty—why do we keep doing them?

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Abstract Recovery room radiographs (RRR) are routinely performed after total knee arthroplasty (TKA). This study investigates the utility of these radiographs. Twenty four arthroplasty surgeons were surveyed to rank the value of RRRs. Since RRRs were primarily valued for educational purposes, we examined the ability of 49 orthopaedic trainees to determine the coronal alignment of TKA performed in cadaveric specimens based on these radiographs in neutral, 10° internal and external rotations. Surgeons rated the quality of the RRRs to be significantly lower than the radiographs taken in the radiology suite (5.5 ± 2.5 versus 8.9 ± 0.9 , $p < 0.0001$). Of an estimated 65,910 TKAs performed by these surgeons, only eight cases (0.01%) required same day revision based on the RRR. Neutral alignment was significantly more accurately ($p < 0.0001$) interpreted than valgus or varus (69.4% versus 42.9% and 16.3%, respectively). Surprisingly, internal rotation of the limb significantly improved interpretation of both varus (from 16.3% to 40.8%, $p = 0.014$) and valgus (from 42.9% to 63.3%, $p = 0.048$). Increased level of orthopaedic training did not significantly affect the accuracy of interpretation ($p = 0.46$).

Interpretation of RRRs for coronal malalignment is inaccurate and has a limited educational value.

Introduction

Total knee arthroplasty (TKA) is widely recognised as an effective procedure for treatment of a variety of knee arthropathies. Advancements in surgical technique and implant designs, as well as patients' increased awareness, have led to tripling of the rate of TKAs performed annually in the United States. As a consequence, the number of primary TKAs has increased from 129,000 in 1990 to 381,000 in 2002 and is expected to surpass 500,000 per year in the United States by 2030 [1–6].

TKA aims to provide patients with long-term improvement in function and substantial pain relief. In the absence of complications due to infection and co-existing medical conditions, mechanical failure has been stated as a primary cause for early TKA revision [7]. Previous studies have reported that appropriate coronal alignment is important for implant longevity. Varus or valgus malalignment of more than 3° is considered clinically significant and is believed to be associated with increased rates of loosening in the longer term (24% versus 3% at 8 years) [8].

With the advent of computer-assisted navigation systems (CAS), the coronal alignment of the TKA can be rather accurately established intra-operatively [9]. CAS technology can determine the coronal alignment of the femur, tibia, and lower limb using specific anatomical landmarks thereby providing immediate feedback to surgeons and trainees [10]. Furthermore, Graydon et al. [10] demonstrated that the accuracy is not affected when CAS is used in specimens with pre-existing abnormal coronal alignments. Yet, a positive clinical correlation to improved alignment

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attained using a navigation system has not been consistently shown in the literature [11, 12].

The current practice in many hospitals is to routinely perform recovery room radiographs (RRR) immediately after TKA in order to detect technical flaws (such as femoral notching, free cement, periprosthetic fractures), which may influence the postoperative rehabilitation protocol and weight bearing status.

However, these portable radiographs are performed in the setting of the recovery room under suboptimal conditions (i.e. limited capacity for patient assistance, bulky dressings, crowded settings, portable equipment) and may unnecessarily expose the recovery room personnel and other patients to radiation. It also entails additional costs (technician time and portable machine costs), while the accuracy may be diminished due to improper positioning of the extremity.

Initially, this study analysed the underlying reasons for arthroplasty surgeons' practice of performing recovery room post-TKA radiographs by using a specifically designed survey. The second part of the study had several objectives:

1. To examine the ability of orthopaedic trainees to determine coronal alignment of TKA components based on anteroposterior (AP) radiographs
2. To determine what the influences of internal rotation (IR) and external rotation (ER) of the knee are on the interpretation of coronal alignment of these radiographs
3. To determine if these results are significantly influenced by the level of orthopaedic training

Methods

Blinded surveys were distributed among 24 arthroplasty surgeons working at six university hospitals. Demographic information including number of years in practice and an estimated number of TKAs performed annually was collected. Surgeons then ranked the value of a RRR in terms of their utility in the assessment of femoral notching, component positioning (femoral lateralisation, tibial overhang), alignment (varus, valgus), presence of foreign bodies and for medicolegal documentation purposes using a 0-to-10 Likert scale (zero representing the lowest value and ten the highest). Surgeons were asked to rank the overall value of RRRs and radiographs performed at the six week postoperative follow-up appointment in the radiography suite.

The incidence of immediate revision TKA based on RRRs in each surgeon's experience was evaluated. In addition, a specific yes/no question was directed at the educational value of these radiographs for orthopaedic trainees (residents, arthroplasty fellows).

In one hospital, in which six of the surgeons practice (cumulative total of 20,690 TKAs), RRRs are performed by technicians specifically trained for this purpose. Their answers to the survey were analysed together with the other surgeons and an additional sub-analysis was performed to compare their evaluation of six-week postoperative radiographs and RRRs in their setting.

Since most surgeons (66.7%) primarily valued RRRs for educational purposes by means of the immediate visual feedback provided, we felt it worthwhile to determine residents' and arthroplasty fellows' ability to correctly interpret such radiographs. We studied the ability of orthopaedic trainees to determine coronal alignment of TKA components in these RRR radiographs.

TKA (Scorpio, Stryker, Kalamazoo, MI) was performed on full-leg cadaveric specimens. The femoral component was inserted at 6° of valgus. The tibial component was implanted in three different coronal alignments: 0°, 3° varus, and 3° of valgus, with a 5° posterior slope. Consequently, the overall alignment of the extremities was neutral, 3° varus, and 3° of valgus.

In each knee, with the aforementioned coronal alignments, anteroposterior (AP) radiographs were performed in 0°, 10° internal rotation, and 10° external rotation. The radiographs were taken as per the protocol used in the recovery room at our institution. The portable X-ray (AMX4, General Electric, Fairfield, CT) was placed 100 cm from the specimen and all radiographs were taken on 24 cm x 30 cm films. The series of nine radiographs were randomised and blinded for rotation and alignment and independently interpreted by 25 junior and 15 senior orthopaedic residents as well as nine arthroplasty fellows at the university affiliated hospitals. Each radiograph was interpreted by the reviewers as clinically neutral (1–2° valgus to 1–2° varus), clinically significant varus ($\geq 3^\circ$ varus) or clinically significant valgus ($\geq 3^\circ$ valgus) without the use of measuring devices or computer programs.

Source of funding

TKA implants were provided for the study courtesy of Stryker, Canada. However, no external funding was provided by this company and they were not involved in the investigation of the study.

Statistical analysis

A chi-square test was used to compare overall scores of RRRs to radiographs performed at six weeks postsurgery. A Kruskal-Wallis test was used to compare the scores of the orthopaedic trainees in detecting each coronal alignment (clinical varus, valgus and neutral). In addition, the Kruskal-

Wallis test was used to compare the scores between the different groups of the orthopaedic trainees (junior residents, senior residents and arthroplasty fellows), while the Fisher's exact test was used to compare the scores between different rotations in each group of trainees. A Mann-Whitney test was used to examine the influence of rotation on the scores of detecting coronal alignment. For all statistical tests a significance level of $p < 0.05$ was chosen.

Results

Surgeon survey

Twenty four arthroplasty surgeons with an average estimate of 138.3 ± 84.9 (median 127.5, range 25–400) TKAs performed annually and average of 16.8 ± 10.3 (median 15.5, range 1–35) years in practice participated in the study. The overall estimate of TKAs performed by these surgeons was 65,910. Eight cases (0.01%) required same day revision based on immediate RRRs. Only five (20.8%) surgeons recalled such incidents, with a rate of $0.4\% \pm 0.1$ (range 0.1–0.5%). Reasons for immediate revision as documented by our survey included an undisplaced medial condyle fracture which was not recognised during surgery, excessive notching of the femur which was estimated to be a risk for a periprosthetic fracture, as well as penetration of the tibial cortex by a malaligned tibial component's keel in a knee which had previously undergone a high tibial osteotomy.

The average value of the immediate RRR was $6.8/10 \pm 3.3$ for femoral notching, $6/10 \pm 3.4$ for components coronary alignment, $3.8/10 \pm 2.7$ for foreign bodies and $3.6/10 \pm 3.1$ for medicolegal documentation prior to weight bearing and rehabilitation (Table 1). Overall RRRs were ranked as significantly inferior to the six-week postoperative radiographs (5.5 ± 2.5 versus 8.9 ± 0.9 , $p < 0.0001$).

In one of the surveyed hospitals (six surgeons with a total of 20,690 TKAs) these radiographs were taken exclusively by specially trained technicians in order to address the surgeons' concerns about the quality of these radiographs. The average score of RRRs graded by surgeons of that hospital was $8.3/10 \pm 1$. This score was significantly better ($8.3/10 \pm 1$ versus 5.5 ± 2.5 , $p < 0.0001$) than the immediate RRR from other hospitals, yet it was still significantly worse than the average ranking of six-week follow-up radiographs performed in their own hospital ($8.3/10 \pm 1$ versus 9.5 ± 0.6 , $p = 0.04$).

Coronal alignment interpretation

Neutral alignment was significantly better ($p < 0.0001$) detected than valgus or varus malalignment (69.4% versus

42.9% and 16.3%). IR of the limb significantly improved overall interpretation of both varus (from 16.3% to 40.8%, $p = 0.014$) and valgus (from 42.9% to 63.3%, $p = 0.048$). Although the overall rates of accurate interpretation of coronal alignment correlated to the level of orthopaedic training (45.8% in junior residents versus 48.1% in senior residents and 53.1% in arthroplasty fellows), this difference was not found to be statistically significant ($p = 0.46$).

Junior orthopaedic residents

Neutral coronal alignment was correctly interpreted by 64% of the junior residents in neutral rotation as well as 64% in IR and 68% in ER. Their score in accurately detecting clinically significant varus malalignment improved from 16% in neutral rotation as well as in ER to 32% in IR. Similarly, their score in accurately detecting clinically significant valgus malalignment improved from 40% in neutral rotation as well as in ER to 72% in IR (Table 2).

Senior orthopaedic residents

Neutral coronal alignment was identified by 80% of the senior residents in neutral rotation as well as 53.4% in IR and 73.3% in ER. Their ability to accurately detect clinically significant varus malalignment improved from 13.3% in neutral rotation and 20% in ER to 46.7% in IR. Their score in accurately detecting clinically significant valgus malalignment remained essentially the same (46.7% in neutral rotation as well as in IR and 53.3% in ER, Table 3).

Arthroplasty fellows

Neutral alignment was identified by 66.7% of the arthroplasty fellows in neutral rotation as well as 55.6% in IR and 88.9% in ER. Their score in accurately detecting clinically significant varus malalignment improved from 22.2% in neutral rotation and 33.3% in ER to 55.6% in IR. Their score in accurately detecting clinically significant valgus malalignment improved from 44.4% in neutral rotation and ER to 66.7% in IR (Table 4).

Discussion

The post-TKA radiograph in the recovery room is a traditional aspect of care in many institutions, with the objective of visualising the position and alignment of the tibial and femoral components. This information provides feedback to both the treating surgeon and any associated orthopaedic trainees. It is essentially considered a component of quality control. However, such radiographs have been a

Table 1 Arthroplasty surgeon data

Surgeon	Annual TKAs	Years of practice	Overall TKAs	Questionnaire topics									
				Quality of RRR	Quality of postop radiographs	Notching	Position	Alignment	Foreign body	Medicolegal	Incidence of revision	Total immediate revision	Educational value
1	100	30	3,000	2	10	2	10	10	0	0	0.0%	0	No
2	150	30	4,500	5	8	10	6	5	0	0	0.5%	0	Yes
3	125	24	3,000	7	10	8	5	3	8	8	0.1%	2	Yes
4	200	30	6,000	8	10	10	2	2	5	2	0.1%	1	No
5	230	28	6,440	10	10	3	10	10	2	0	0.0%	0	Yes
6	130	20	2,600	9	9.5	4	2	1	3	5	0.0%	0	Yes
7	100	26	2,600	7.5	8.5	8	5	5	5	8	0.0%	0	Yes
8	50	1	50	8	9	10	7	9	6	8	0.0%	0	Yes
9	175	22	3,850	3	8	8	7	7	3	4	0.1%	2	Yes
10	250	10	2,500	8	10	8	10	8	8	8	0.0%	1	Yes
11	175	4	700	7	9	10	9	8	4	6	0.0%	0	No
12	100	1	100	7	9	10	7	7	8	6	0.0%	0	Yes
13	30	6	180	6	9	10	5	3	1	1	0.0%	0	Yes
14	90	12	1,080	8	9	8	8	9	7	7	0.0%	0	Yes
15	25	6	150	6	8	8	8	7	3	2	0.0%	0	Yes
16	400	35	14,000	5	8	8	8	8	5	5	0.0%	0	Yes
17	40	12	480	N/A	10	0	10	10	0	0	0.0%	0	No
18	120	25	3,000	N/A	10	4	2	1	3	0	0.0%	0	No
19	150	15	2,250	3	8	6	8	9	3	2	0.0%	0	Yes
20	200	8	1,600	5	8	6	6	5	3	5	0.0%	0	Yes
21	150	10	1,500	5	7	10	7	6	7	5	0.0%	0	No
22	190	23	4,370	4	8	8	2	0	5	5	0.1%	2	Yes
23	40	9	360	N/A	10	3	10	10	1	0	0.0%	0	No
24	100	16	1,600	3	8	0	0	0	0	0	0.0%	0	No
Total/average			65,910	5.5	8.9	6.8	6.4	6.0	3.8	3.6		8	

TKA total knee arthroplasty, RRR Recovery room radiographs

Table 2 Junior orthopaedic residents

	Actual coronal alignment	Apparent coronal alignment	Limb rotation		
			10° IR	NR	10° ER
<i>IR</i> internal rotation, <i>NR</i> neutral rotation, <i>ER</i> external rotation ^a $\geq 3^\circ$ valgus ^b 1–2° valgus to 1–2° varus ^c $\geq 3^\circ$ varus	3° valgus	Valgus ^a	72% (18)	40% (10)	40% (10)
		Neutral ^b	12% (3)	60% (15)	44% (11)
		Varus ^c	16% (4)	0	16% (4)
	Neutral	Valgus ^a	20% (5)	24% (6)	16% (4)
		Neutral ^b	64% (16)	64% (16)	68% (17)
		Varus ^c	16% (4)	12% (3)	16% (4)
	3° varus	Valgus ^a	28% (7)	0	0
		Neutral ^b	40% (10)	84% (21)	84% (21)
		Varus ^c	32% (8)	16% (4)	16% (4)

common topic for debate due to potential misinterpretations, improper limb position, lack of cost-effectiveness, disputed impact on postoperative management, and radiation exposure to the healthcare staff and other patients in the recovery room.

There were several limitations to our study. First, the number of TKAs that required immediate revision based on RRR was only an estimate rather than actual documented surgical reports. Since the records pertaining to these patients were not actually identified and reviewed, we cannot verify the reason for immediate revision and their subsequent clinical course. However, this limitation is balanced by the wide experience and long-term perspective of 24 arthroplasty surgeons in academic hospitals affiliated with a major university. The second limitation is that the orthopaedic residents assessed have varying degrees of exposure to arthroplasty in their training. This limitation was controlled by the fact that all residents (100% of junior and senior) in the university program in question were included in the study and compared to arthroplasty fellows.

The first part of this study included a survey with an estimate of 65,910 TKAs performed by 24 arthroplasty

surgeons with up to 35 years of experience. Same day revision TKAs were performed only rarely (0.01%). Nineteen (79.2%) surgeons do not recall any such events, while even among the five surgeons who reported same day revision TKAs their rate was $0.4\% \pm 0.1$ (range 0.1–0.5%). This is consistent with the findings in the literature which have shown that immediate RRRs have not altered postoperative management [13, 14].

All surveyed surgeons in this study consistently ranked the RRR to be inferior (5.5 ± 2.5 versus 8.9 ± 0.9 , $p < 0.0001$) to the radiology suite follow-up radiographs. In one of the hospitals RRRs were taken only by specially trained technicians in order to improve their quality. The average score of RRRs in that hospital was significantly better than the immediate RRRs from other hospitals (8.3 ± 1 versus 5.5 ± 2.5 , $p < 0.001$), yet it was still significantly worse ($p = 0.04$) than the average radiology suite follow-up radiographs (9.5 ± 0.6) performed in their own hospital.

Despite their lower overall quality score, 16 (66.7%) of the 24 surgeons consider RRRs to have an educational value for orthopaedic trainees. The educational literature in the realm of motor skills provides some understanding of

Table 3 Senior orthopaedic residents

	Actual coronal alignment	Apparent coronal alignment	Limb rotation		
			10° IR	NR	10° ER
<i>IR</i> internal rotation, <i>NR</i> neutral rotation, <i>ER</i> external rotation ^a $\geq 3^\circ$ valgus ^b 1–2° valgus to 1–2° varus ^c $\geq 3^\circ$ varus	3° valgus	Valgus ^a	46.7% (7)	46.7% (7)	53.3% (8)
		Neutral ^b	40% (6)	53.3% (8)	20% (3)
		Varus ^c	13.3% (2)	0	26.7% (4)
	Neutral	Valgus ^a	33.3% (5)	13.3% (2)	6.7% (1)
		Neutral ^b	53.4% (8)	80% (12)	73.3% (11)
		Varus ^c	13.3% (2)	6.7% (1)	20% (3)
	3° varus	Valgus ^a	6.6% (1)	0	0
		Neutral ^b	46.7% (7)	86.7% (13)	80% (12)
		Varus ^c	46.7% (7)	13.3% (2)	20% (3)

Table 4 Arthroplasty fellows

Table 4 Arthroplasty fellows	Actual coronal alignment	Apparent coronal alignment	Limb rotation		
			10° IR	NR	10° ER
<i>IR</i> internal rotation, <i>NR</i> neutral rotation, <i>ER</i> external rotation ^a ≥3° valgus ^b 1–2° valgus to 1–2° varus ^c >3° varus	3° valgus	Valgus ^a	66.7% (6)	44.4% (4)	44.4% (4)
		Neutral ^b	22.2% (2)	55.6% (5)	22.2% (2)
		Varus ^c	11.1% (1)	0	22.2% (2)
	Neutral				N/A 11.1% (1)
		Valgus ^a	22.2% (2)	33.3% (3)	11.1% (1)
		Neutral ^b	55.6% (5)	66.7% (6)	88.9% (8)
	3° varus	Varus ^c	22.2% (2)	0	0
		Valgus ^a	33.3% (3)	0	11.1% (1)
		Neutral ^b	11.1% (1)	66.7% (6)	55.6% (5)
		Varus ^c	55.6% (5)	22.2% (2)	33.3% (3)
			N/A 11.1% (1)		

the influence of delaying knowledge of results on motor learning [15, 16]. Although these studies do not involve intricate, multi-step motor tasks adequately simulating the complexity of TKA, they collectively show that increasing the duration between conduct of the procedure and the knowledge-of-results from minutes to weeks is not detrimental [15]. Thus, there is no evidence to support an added educational value to performing radiographs in such close temporal proximity to the TKA.

The second phase of the study examined the ability of orthopaedic residents with various degrees of training and arthroplasty fellows to evaluate clinical coronal alignment. AP radiographs were performed in neutral rotation as well as in 10° of IR and ER, as previous reports have shown that rotation can lead to a significant increase in apparent varus and valgus misinterpretation by orthopaedic professionals [17–20]. Since malalignment $>3^\circ$ is regarded as clinically significant [8] and associated with early loosening of TKA components, we aligned TKA components in neutral, 3° varus, and 3° of valgus of the tibial component with a femur in 6° of valgus relative to the mechanical axis in a cadaveric model.

Neutral alignment was significantly better ($p<0.0001$) detected than valgus or varus malalignment (69.4% versus 42.9% and 16.3%). IR of the limb significantly improved overall interpretation of both varus (from 16.3% to 40.8%, $p=0.014$) and valgus (from 42.9% to 63.3%, $p=0.048$). Increased level of orthopaedic training did not significantly affect the accuracy of coronal alignment detection ($p=0.46$).

The conditions in the recovery room are suboptimal and may obscure the quality of post-TKA RRRs. In the time immediately following surgery, patient positioning for radiographs is rarely a priority for recovery room nurses or patients themselves. Patient compliance is often limited by postoperative pain and the bulky dressings which inhibit full extension of the knee. Flexion of the knee has been

shown to significantly increase apparent valgus angulation [21]. In addition, RRRs are non-weight bearing radiographs which have been shown to have an average of 2° less varus versus a standing radiograph [22]. These potential aberrations are consistent with the findings of Glaser et al. [13] which found that only 36% of the post-TKA radiographs provided an accurate baseline for further studies. Other reports have shown that radiographs performed in the radiography suite are significantly superior to the radiographs taken in the recovery room setting [13, 23].

Radiography accounts for over 90% of all radiation exposure in the population [24]. Thus, a large number of other healthcare professionals and patients are within relative proximity and, despite attempts at minimisation, are unnecessarily exposed to radiation.

It is the authors' contention that post-TKA radiographs are preferably performed in the setting of the radiology department, after removal of bulky dressings, on postoperative day one or at some point prior to the patient's discharge from the hospital. Thus, unnecessary exposure by staff to radiation will be eliminated and radiographs will be of better quality. In our opinion, this modification can reduce the need for the first radiographs in follow-up in the majority of patients who follow a normal course of clinical recovery. In addition, this protocol allows performance of long radiographs which further enhances their utility for trainee feedback [20].

If deemed necessary, this study indicates that radiographs obtained in the recovery room are better performed by specifically trained technicians, although they will still result in lower quality images when compared with those done in the radiology suite.

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