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Perioperative Operating Room Efficiency Can Make Simultaneous Bilateral Total Hip Arthroplasty Cost-effective: A Proposal for a Value-sharing Model

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ABSTRACT

Background: Increasing demand for total hip arthroplasty (THA) and rising health-care costs have led hospitals to improve operating room (OR) efficiency. We compare the cost-effectiveness of a simultaneous bilateral THA to that of staged unilateral procedures following the implementation of OR efficiency strategies.

Methods: Between 2017 and 2019, 446 simultaneous and 238 staged bilateral primary THA patients (mean age 61.3 ± 12.0 years; 41.8% males/58.2% females; mean body mass index 27.2 ± 4.8 kg/m^2) were treated by a single surgeon using an efficient, standardized workflow for efficient direct anterior approach THA on a standard operating table. There were no differences in inclusion criteria between both groups. From this cohort, 16 simultaneous bilateral THAs and 34 unilateral THAs were prospectively compared for cost-effectiveness using detailed timestamp measurements and data on personnel and material usage. Outcome was assessed based on complication and reoperation rate and patient-reported outcome measures.

Results: There was a complication rate of 1.2%, without a difference between patients who underwent a simultaneous THA vs those who underwent a staged primary THA (5/446; 1.1% vs 3/238; 1.3% $P = .386$). The mean OR time (patient in/out and turnover time) was 109.4 ± 19.8 minutes for bilateral THAs and 133.8 ± 12.8 minutes for 2 unilateral THAs ($P < .001$). An 18% time-saving and 14% cost-saving was achieved per procedure. Sharing 5% of the cost-saving with the surgeon brings benefit to both the hospital and surgeon.

Conclusions: Implementing OR efficiency improves cost-effectiveness of simultaneous bilateral THA compared to unilateral procedures. A new value-sharing model could be a solution to align incentives.

Introduction

In the last 2 decades, the demand for total hip arthroplasty (THA) has been rising with the expanding aging population. Since 2000, the number of THA surgeries is increasing rapidly in most Organization for Economic Cooperation and Development countries [1]. In the United States alone, THA procedures are projected to increase by 174% to 572,000 by 2030 [2]. It is predicted that this will create an unsustainable burden for many health-care systems including those of the United States and Europe [3].

Costs related to surgical care are reported to be 40% of all hospital costs [4,5] which has prompted several institutions to improve operating room (OR) efficiency [6–8]. Surgeons are uniquely positioned to play a leading role in this effort. As a result, more responsibility is being placed on the surgeon to minimize OR costs

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while continuing to deliver optimal care. Growing emphasis on value-based health care [9] with time-driven activity-based cost models [10] indicates a shift in accountability for defining value structures and increases motivation to reduce costs wherever possible, including the OR. As a result, there is greater incentive for surgeons to drive OR efficiency initiatives [8].

Patients requiring bilateral THAs provide the potential to achieve more efficiency while maintaining a high standard of care. Several studies have shown that with careful patient selection, a single-stage bilateral THA procedure is as safe and efficacious as 2 unilateral procedures [11–16]. In addition, the simultaneous bilateral THA has been shown to be cost-effective [13,14,17–19]. Nevertheless, the prevailing approach toward patients with bilateral end-stage osteoarthritis of the hip remains a staged unilateral THA procedure. As far back as 1998, studies have demonstrated the cost-effectiveness of a simultaneous bilateral procedure against 2 unilateral procedures with a reduced spending of 24%-25% for a bilateral procedure [18,19]. However, reimbursement structures do not incentivize a bilateral THA, where the surgeon is compensated 50% less for the second side when done simultaneously [17].

In this study, we aimed to assess safety and cost-effectiveness of a simultaneous bilateral primary efficient direct anterior (EDA) THA in comparison to a staged bilateral primary direct anterior approach THA in patients with bilateral hip arthritis, after implementing a consistent and standardized OR workflow. By doing so, we suggest a value-sharing model that can serve as a tool to align incentives in driving OR efficiency to meet the needs in our contemporary health-care environment.

Material and methods

Study design and study population

This is a prospective case-control study in which the economic parameters of 16 simultaneous bilateral THA procedures were compared with those of 34 unilateral THA procedures operated on 16 OR days between January and December 2019 by a single surgeon (K.C.) in 1 tertiary referral center. All patients had severe end-stage hip osteoarthritis and were randomly chosen. The mean age was 61.5 ± 5.5 years (range: 39-82), and the mean body mass index (BMI) was 26.5 ± 12.2 kg/m^2 (range: 17-38), without significant differences between both groups ($P = .77$ and $P = .68$, respectively).

Patients are scheduled for a simultaneous bilateral primary THA in case of severe bilateral hip disease (end-stage arthritis or avascular necrosis).

A retrospective analysis of a prospectively recorded database of 1879 patients that underwent 2189 THAs between January 2017 and December 2019 by the same surgeon showed that 223 patients underwent a simultaneous bilateral THA (n = 446) and 119 patients a staged bilateral THA (n = 238), after excluding patients younger than 18 years; with a history of previous intramedullary nail, hip fusion, femoral neck fracture, posttraumatic arthritis, or fracture nonunion; and a history of septic arthritis (Fig. 1). Patients with simultaneous bilateral THAs were younger (60.5 ± 11.7 years vs 63.0 ± 12.4 years; $P = .006$), had a lower BMI (26.8 ± 4.7 kg/m^2 vs 28.0 ± 5.0 kg/m^2; $P = .003$), and a lower American Society of Anesthesiologists grade ($P < .001$). There was no difference in sex distribution ($P = .567$) or indication ($P = .126$) (Table 1).

Description of standardized OR workflow

All surgeries were conducted using a standardized workflow for direct anterior hip THAs using a regular operating table [20–22]. This process, which we refer to as the EDA method, was initiated in our hospital in 2016 [20–22]. All the EDA procedures are conducted by the same surgical team with extensive experience with the approach, on a regular OR table, without femoral hyperextension. The same cementless implant is used in all cases (Pinnacle–Corail; DePuy-Synthes, Warsaw, IN).

The EDA procedure utilizes 3 measures to standardize the overall OR workflow. The procedure can be conducted by 1 surgeon and 1 scrub tech. First, the procedure is conducted on a regular OR

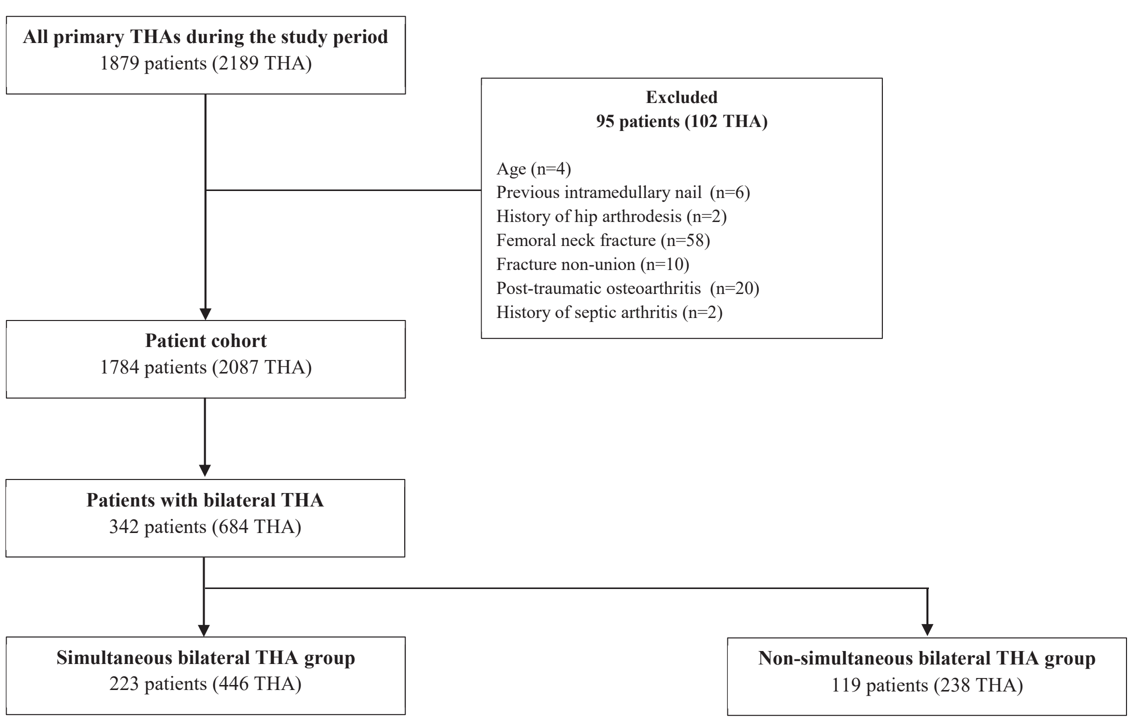

Figure 1. Flowchart of the cohort included in the study.

Table 1
Demographic data of the cohort.

Parameter	Whole cohort (n = 684)	Simultaneous bilateral THA group (n = 446)	Nonsimultaneous bilateral THA group (n = 238)	*P* value
Mean age at THR, y ± SD (range)	61.3 ± 12.0 (21.8-86.1)	60.5 ± 11.7 (21.8-84.1)	63.0 ± 12.4 (24.0-86.1)	.006[d,b]
Sex				.567[c]
Male (n, %)	286 (41.8%)	190 (42.6)	96 (40.3)	
Female (n, %)	398 (58.2%)	256 (57.4)	142 (59.7)	
BMI, mean ± SD (range)	27.2 ± 4.8 (18.0-45.7)	26.8 ± 4.7 (18.0-45.7)	28.0 ± 5.0 (18.1-42.2)	.003[d,b]
Mean follow-up, y ± SD (range)	2.6 ± 0.9 (1.0-3.9)	2.6 ± 0.9 (1.0-3.9)	2.6 ± 0.8 (1.0-3.9)	.344[c]
Indication				.126[c]
Primary hip osteoarthritis, n (%)	502 (73.4)	338 (75.8)	164 (68.9)	
Secondary hip osteoarthritis to dysplasia,[a] n (%)	170 (24.9)	102 (22.9)	68 (28.6)	
AVN, n (%)	6 (0.9)	2 (0.4)	4 (1.7)	
LCPD/SCFE sequelae (n, %)	6 (0.9)	4 (0.9)	2 (0.8)	
ASA				
Grade 1	375 (54.8)	271 (60.8)	104 (43.7)	<.001[d,c]
Grade 2	280 (40.9)	164 (36.8)	116 (48.7)	
Grade 3	29 (4.2)	11 (2.5)	18 (7.6)	

AVN, avascular necrosis; ASA, American Society of Anesthesiologists; LCPD, Legg-Calvé-Perthes disease; SCFE, slipped capital femoral epiphysis; SD, standard deviation.
[a] Secondary hip arthritis due to dysplasia as per lateral center-edge angle ≤20°.
[b] Mann-Whitney U test.
[c] Chi-square test.
[d] Statistically significant (*P* value < .05).

Figure 2. (a and b) Both arms are folded over the chest. This prevents the arm from being in the way during femoral preparation when the surgeon is standing at the level of the chest of the patient. (c) The 2 surgical windows in the EsySuit draping system allows for simultaneous draping of both hips in case of single-stage bilateral THA. (d) A contralateral side table at the level of the mid-tibia is important for external rotation during the femoral elevation maneuver. The ipsilateral foot is put on top of the side table. The ipsilateral leg is pulled in an adducted position by the scrub nurse.

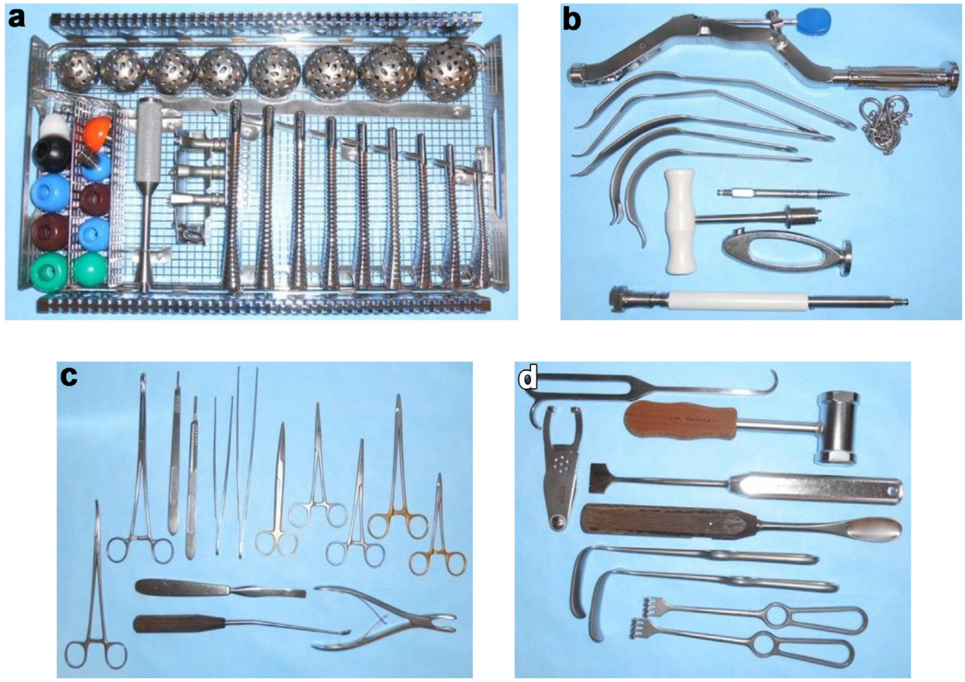

Figure 3. (a) The content of the Corail/Pinnacle Efficient SurgerY instrumentation kit (DePuy-Synthes, Warsaw, IN) is shown. This covers 98% of the cases. Pinnacle socket reamers cover socket sizes from 48 mm to 58 mm. The Corail stem broaches are downsized from 11 to 9 discarding the 2 largest sizes. (b) In total, 5 retractors are required to conduct the EDA procedure. The retractors are curved in the axial direction. The socket impactor is double-curved to facilitate the procedure for more obese patients. A chain is used to hold the calcar retractor during capsular exposure. Other instruments are the corkscrew driver with a T-handle, the straight stem impactor, and the straight reamer handle for the socket. The EDA retractors are sequentially numbered which guides the team members throughout the standardized procedure. The body of every retractor is designed with a curvature in the transverse plane in order to minimize soft-tissue damage. The flat-ended part of the ESY retractors perfectly fits into the slot of the Gripper (MedEnvision, Aarschot, Belgium) which assures a stable retractor placement during the procedure. (c) The content of the ESY OR instrument tray is shown. From left to right, the upper line shows the “small” instruments: 1 instrument for prepping, 2 knives, 2 forceps, 1 scissors, 2 Kocher forceps, and 2 needle holders. The lower line from left to right: 1 hemostat, 1 periosteal elevator, 1 curette, and 1 nibbler. (d) The “larger” OR instruments. From top to down: 1 blunt bone hook, 1 hammer (500 g), 1 femoral head caliper, 1 osteotome, 1 spoon, 2 Langenbeck retractors, and 2 Volkmann retractors.

table with the patient in the supine position. Both legs are prepped simultaneously with the EsySuit draping system (MedEnvision, Aarschot, Belgium). There are 2 surgical windows embedded in the EsySuit which allows for simultaneous draping of both hips in case of single-stage bilateral THA (Fig. 2). This allows for the surgical team to move from one side to the other without the need to redrape the patient. Second, standard surgical instrumentation trays including the Corail–Pinnacle instrumentation have been reduced from 10 to 2 instrument trays and 1 motor tray. In order to do so, a retrospective analysis of 204 cases showed that 96% of acetabular implants had a diameter between 48 mm and 58 mm. Reaming of the acetabular bone is typically done with 1 mm undersizing, limiting the tray to only include odd-sized graters from 43 mm to 57 mm. Similarly, utilized stem sizes were between 8 and 16 allowing for discarding the largest broach sizes. Along with the nursing staff, we critically evaluated which instruments would be really necessary to safely conduct an EDA hip procedure. This allowed for streamlining our OR instrument trays by discarding approximately 70% of our instruments from our regularly used trays (Fig. 3). The most important challenge was to keep the weights of the trays below 19 pounds and 25 pounds to remain within the hospital and the American National Standard Institute, Association for the Advancement of Medical Instrumentation, and Association of periOperative Registered Nurses standards for sterile tray weights, respectively, [23]. In the event it is deemed necessary during a specific case, extra trays with all implant sizes are opened. Finally, a table-mounted, orthostatic retractor placement device (Gripper; MedEnvision, Aarschot, Belgium) is used to hold the flat-ended and shortened retractors in a stable position [24]. This setup eliminates the need for a nurse or assistant to hold the retractors, which minimizes the amount of manpower required to conduct the procedure (Fig. 4). The reduction of the inventory for each EDA case allows for swift OR turn overs (Fig. 5).

Surgical technique

Briefly, the procedure consists of 3 major steps [22]. First, capsular exposure is achieved through a groin crease incision. The second step is the capsular releasing sequence which starts with the release of the anterior capsule. After the femoral neck osteotomy and extraction of the femoral head, the ipsilateral leg is put on top of the contralateral leg. With this “lazy figure of four position,” the ipsilateral leg is externally rotated with a good visibility of the calcar. This allows for the release of the pubofemoral ligament. The final part of the capsular release, with the leg in neutral position, is the superior capsulotomy, which is started at the greater trochanter and typically does not extend beyond the border of the posterior cortex of the femoral neck. This preserves the posterior capsule and the insertion sites of the short external rotators. The final and third step of the EDA hip procedure is component insertion, which starts with the acetabular preparation. Three retractors are used to expose the acetabulum with an excellent view of the transverse acetabular ligament. The goal of socket-positioning is to place the socket parallel to the transverse acetabular ligament and to aim for 30°-35° of inclination and 15°-20° of anteversion. Next, the femur is elevated and adducted underneath the contralateral leg without femoral hyperextension. After femoral broaching, the trial implant is checked for stability through a full range of motion including deep flexion-internal rotation and extension-external rotation to make sure the implant positioning is in a “functional safe zone.” No intraoperative

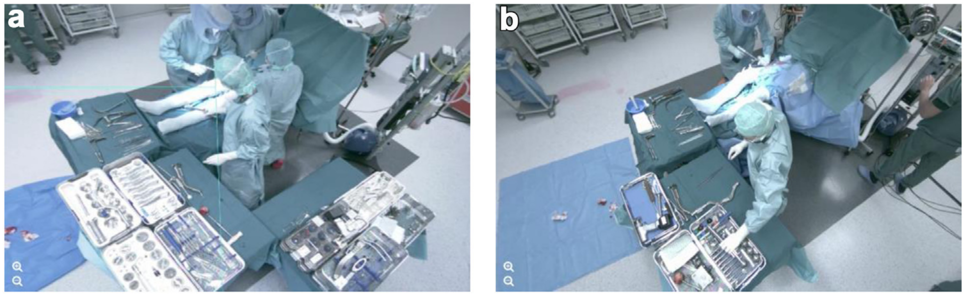

Figure 4. OR overview showing the transition from (a) the traditional DAA to (b) the EDA hip. (a) Multiple trays and 2 nurses are required to conduct the procedure. Selecting out the correct instruments and structuring all trays require more time and skills, which leads to variability in the OR setup. This leads to variations in OR execution and long turnover times. (b) The reduction of instrument trays has led to reproducibly in setting up a standardized OR. The EDA hip procedure can be conducted with 1 scrub nurse. This allows for reallocation of manpower. DAA, direct anterior approach.

fluoroscopy is used. Leg length is tested with the legs extended and the Galeazzi test for femoral length. Finally, closure starts with suturing of the medial-based anterior flap. All patients are fully mobilized on day one postoperatively without any restrictions. In case of single-stage bilateral THAs, the surgical team moves to the contralateral side and uses the same instruments and OR setup.

Clinical assessment

Outcome measures were prospectively recorded and included patient-reported outcome measures (PROMs), complication rates, and reoperation rates. The Clavien-Dindo classification was used to grade complications [25].

PROMs were obtained at 4 weeks preoperatively and at the time of the patient's latest follow-up (minimum 1 year postoperatively). These included the Hip Disability and Osteoarthritis Outcome Score [26] and 36-item Short Form Survey [27].

Timing measurements, personnel, and material usage

For each case, over 50 timestamps were measured by trained observers inside the OR using a validated process. To validate the process, a mean deviation of less than 20 seconds was deemed

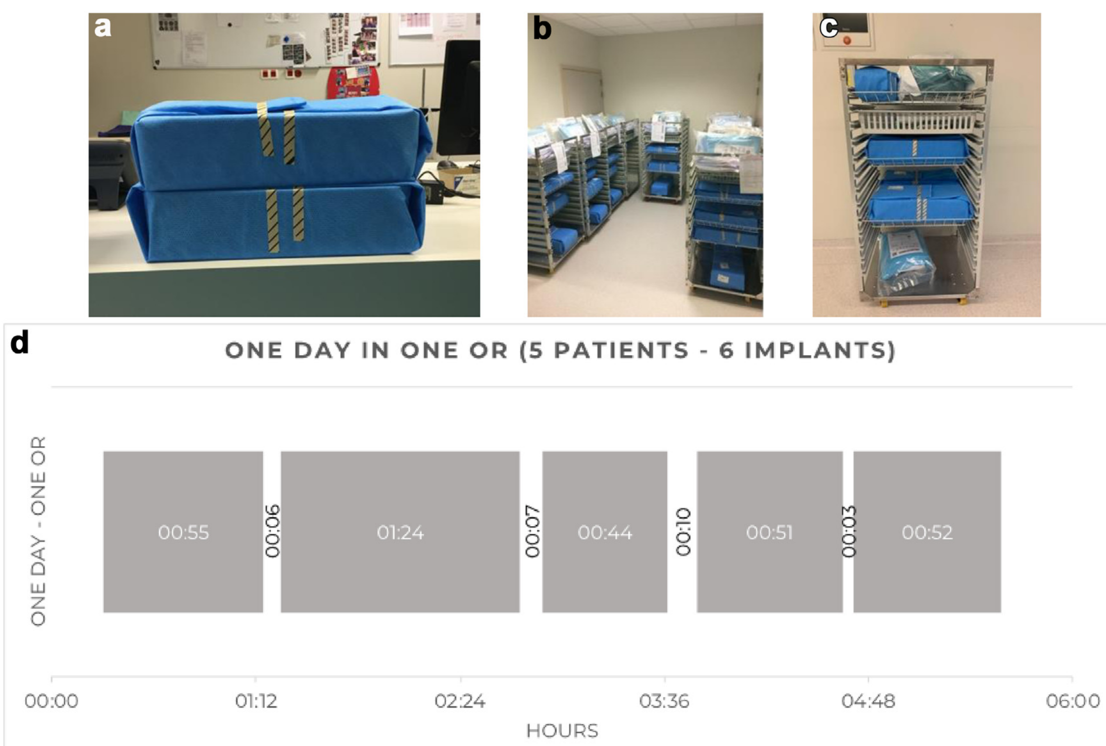

Figure 5. (a) The Efficient SurgerY (ESY) instrument Kit for the Corail-Pinnacle THA consists of 2 well-structured trays with a maximum weight of 8.5 kg (19 pounds) per tray. More than 98% of all primary EDA cases are fully covered with all the instruments in these 2 trays. A third tray contains the power tools. (b) Due to the OR tray reduction with the ESY Kit, we were able to condense all OR equipment into 1 EDA trolley. The logistics of in total 10 EDA cases can now be condensed into 1 room. (c) Each case trolley is structured in the same way. From top to bottom: consumables, 1 power tool tray, the ESY Instrument kit, and 1 EsySuit. (d) This allows for low OR turnover times as visualized through this example of a single day in the OR.

Table 2
Patient-reported outcome measures.

Type of complication	Whole cohort (n = 684)	Simultaneous bilateral THA group (n = 446)	Staged bilateral THA group (n = 238)	P value
Grade 1 (requiring physiotherapy, analgesia)	20 (2.9)	9 (2.0)	11 (4.6)	.054[b]
Psoas tendinopathy	13 (1.9)	6 (1.3)	7 (2.9)	
Hematoma	5 (0.7)	2 (0.4)	3 (1.3)	
Femoral nerve neuropraxia	2 (0.3)	1 (0.2)	1 (0.4)	
Grade 2 (requiring pharmacologic treatment)	1 (0.1)	0 (0.0)	1 (0.4)	.121[c]
Wound complications requiring antibiotics pulmonary embolism	1 (0.1)	0 (0.0)	1 (0.4)	
Grade 3 complications (requiring reoperations)	8 (1.2)	5 (1.1)	3 (1.3)	.386[b]
Extra-articular impingement, n (%)	3 (0.4)	3 (0.7)	0 (0.0)	
Dislocation (close reduction), n (%)	2 (0.3)	1 (0.2)	1 (0.4)	
Periprosthetic fracture (ORIF), n (%)	1 (0.1)	0 (0.0)	1 (0.4)	
Wound complications, n (%)	2 (0.3)	1 (0.2)	1 (0.2)	
Grade 3 complications (requiring revision)				.347[c]
Periprosthetic fracture (stem revision), n (%)	1 (0.1)	0 (0.0)	1 (0.4)	

ORIF, open reduction and internal fixation.
[b] Chi-square test.
[c] Fisher exact test.

acceptable for intraobserver and interobserver measurements due to the limited impact on the timestamps. The mean difference for intrarater measurements is 2.0 ± 2.2 seconds, whereas interrater measurements have a mean difference of 13.7 ± 18.5 seconds. The process validation using a paired t-test showed that there was no significant interobserver difference ($P = .33$, n = 125). To evaluate intraobserver variability, surgical procedures were video-recorded and re-evaluated by the same observer with a 6-week interval. No significant differences in timestamps were found ($P = .73$, n = 44).

Along with timestamps, information around task allocation, procedural flow, and instrumentation flow was also captured by the observers. Outside the OR, data were collected around the operational flows, BMI, and patient age.

Measuring cost-effectiveness

Data for OR cost-estimation were derived from the hospital, the literature, and the Belgian government (Tables A1 and A2, Appendix A). The OR cost per procedure was calculated as a sum of variable and fixed costs. Variable costs included costs associated with the procedure for products (eg, implants, consumables, instruments, drugs) and compensation (ie, surgeon, anesthetist). These costs were equivalent to the reimbursement value provided by the Belgian government. Fixed costs, on the other hand, account for general overheads such as salaried personnel (eg, nursing staff, assisting staff, cleaning staff), maintenance and repair of equipment, utilities, and estate cost. A fixed cost per minute was calculated (7.03€/min or 7.15$/min) and multiplied by the measured

Table 3
Patient-reported outcome measures preoperatively and at the latest follow-up.

Patient reported outcome score	Simultaneous bilateral THA group (n = 446)	Staged bilateral THA group (n = 238)	P value[a]
HOOS symptoms			
Preop (mean ± SD)	31.7 ± 19.1	30.2 ± 17.7	.650
Postop (mean ± SD)	76.3 ± 22.1	72.4 ± 23.8	.002[b]
Δ (mean ± SD)	48.1 ± 24.4	41.9 ± 24.7	.166
HOOS pain			
Preop (mean ± SD)	40.1 ± 19.3	34.4 ± 15.7	.003[b]
Postop (mean ± SD)	83.6 ± 19.3	78.2 ± 26.3	.096
Δ (mean ± SD)	44.1 ± 22.3	43.6 ± 28.6	.757
HOOS activities daily living			
Preop (mean ± SD)	40.3 ± 19.5	33.4 ± 17.2	<.001[b]
Postop (mean ± SD)	84.3 ± 20.5	78.3 ± 25.0	.175
Δ (mean ± SD)	44.9 ± 23.5	44.9 ± 25.7	.788
HOOS sports			
Preop (mean ± SD)	20.4 ± 21.7	12.9 ± 17.4	<.001[b]
Postop (mean ± SD)	68.4 ± 28.9	57.3 ± 33.1	.016[b]
Δ (mean ± SD)	47.0 ± 30.1	45.6 ± 37.6	.991
HOOS quality of life			
Preop (mean ± SD)	25.7 ± 19.5	24.8 ± 16.7	.988
Postop (mean ± SD)	73.7 ± 23.9	72.6 ± 26.3	.958
Δ (mean ± SD)	49.2 ± 26.0	49.3 ± 26.9	.976
SF-36			
Preop (mean ± SD)	46.0 ± 15.8	40.9 ± 40.9	.001[b]
Postop (mean ± SD)	71.8 ± 15.7	67.2 ± 19.1	.102
Δ (mean ± SD)	25.8 ± 17.0	25.8 ± 16.7	.933

HOOS, Hip Disability and Osteoarthritis Outcome Score; SD, standard deviation; SF-36, 36-item Short Form Survey.
[a] Mann-Whitney U test.
[b] Statistically significant (P value < .05).

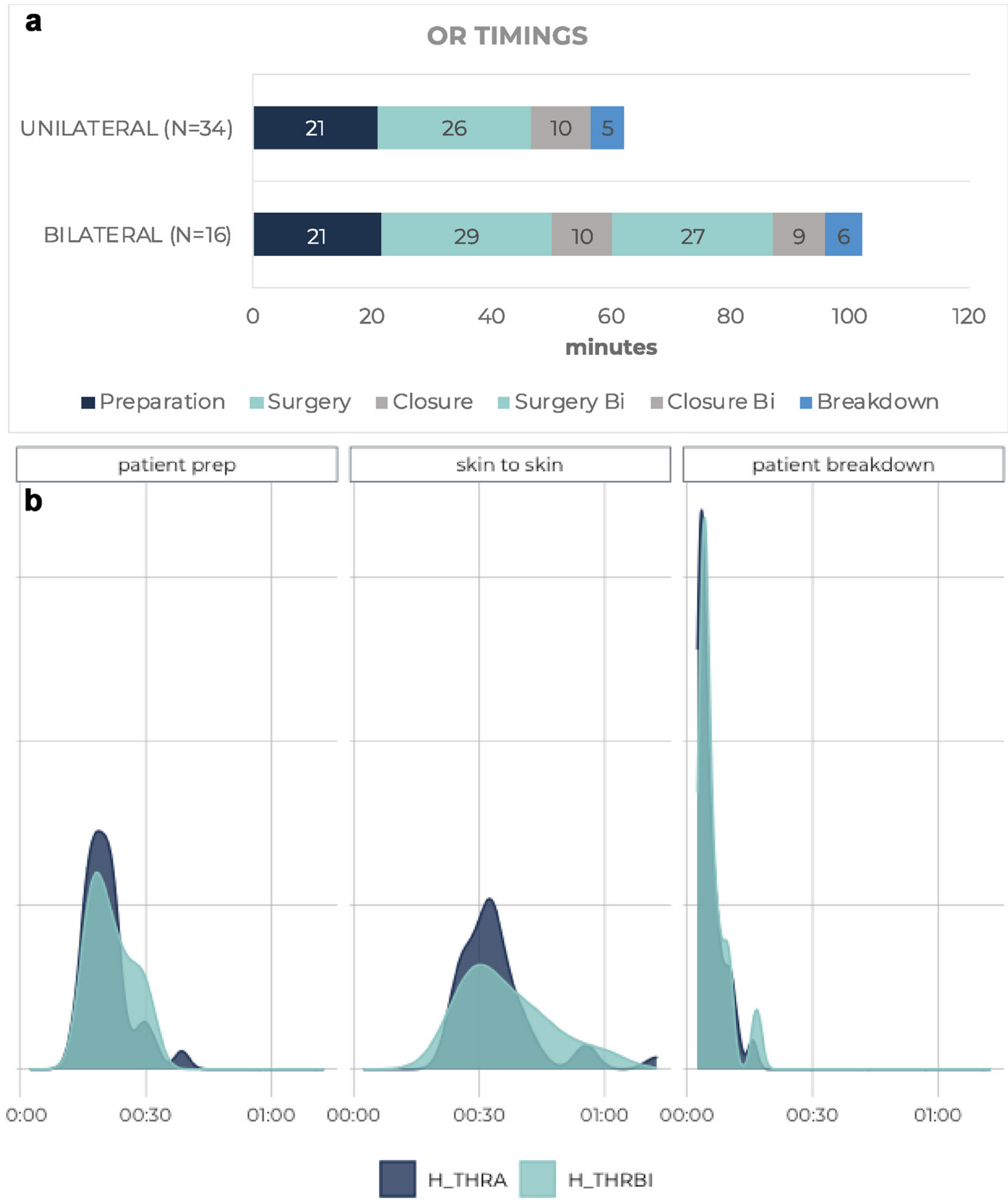

Figure 6. (a) The mean patient in/out time for unilateral and bilateral procedures compartmentalized into subcomponents of procedure preparation, surgery of the first hip, surgery of the second hip, closure of the incision, and breakdown of the OR. (b) The mean and standard deviation of the patient preparation, skin-to-skin time (incision to closure of first hip), and breakdown time show the high level of process consistency for both procedure types. H_THRA, Hip_TotalHipReplacementAnterior (unilateral); H_THRBi, Hip_TotalHipReplacementBilateral.

mean OR time to obtain the fixed cost per procedure, whereas variable costs are directly attributed to the total procedure cost. Additionally, we derived the opportunity cost for more OR days and unilateral cases based on the total number of bilateral and unilateral cases performed by the surgeon in a single year.

Statistical analysis

Efficiency was assessed using time consistency where standard descriptive statistics, including mean and standard deviation, were calculated. Continuous variables were compared using a Mann-Whitney U test using the R statistical programming software [28]. This was conducted on 4 factors: the patient in/out time (patient OR entry to patient OR exit), preparation time (patient OR entry to incision start), breakdown time (undraping patient start to patient OR exit), and surgery time per hip (incision start to closure start). Categorical variables were compared using a chi-square analysis or Fisher exact test. The Mann-Whitney U test was used with a significance level of $P < .05$. The Pearson method was used for analyzing the correlation between continuous variables.

Results

Clinical assessment

The complication rate of patients undergoing a simultaneous bilateral THA was 1.1% for Clavien-Dindo grade 3 complications (5/446) (Table 2). One dislocation (0.2%) in the early postoperative

Table 4
OR cost shows the total OR cost for each procedure along with total OR time.

Variable	Single unilateral	Two unilateral	Bilateral
Total OR time (min)	66.9	133.8	109.4
Total procedure cost	4775€ ($4857)	9550€ ($9714)	8194€ ($8334)
Variable cost	4305€ ($4379)	8610€ ($8758)	7425€ ($7552)
Fixed cost	470€ ($478)	940€ ($956)	769€ ($782)

The cost of 2 unilateral cases is calculated as a single unilateral case multiplied by 2. Values given both in Euro as well as in United States Dollars as per currency Oct 2022 (1.00$ =1.02€).

period required a closed reduction. Two patients (3 hips) had signs of extra-articular impingement (0.7%) and required a surgery to remove ossifications. One patient underwent a wound debridement due to persistent wound leakage (0.2%). No significant differences in complication and reoperation rates were found between patients that underwent a simultaneous bilateral THR and those that underwent a staged bilateral THR ($P = .386$).

Patients that underwent a simultaneous bilateral THA had lower preoperative PROM scores (Hip Disability and Osteoarthritis Outcome Score and 36-item Short Form Survey) than patients with a staged bilateral THA. There was no difference in postoperative PROM scores between both groups (Table 3).

Assessment cost-effectiveness

The patient in/out time for a unilateral THA was 61.9 ± 12.8 minutes compared to the 104.4 ± 19.8 minutes for bilateral THAs (Fig. 6). This is a time-saving of 19.4 minutes or 16% with bilateral THAs compared to staged unilateral THAs ($P < .001$). Preparation and breakdown time were similar for both procedures ($P = .6$ and $P = .5$, respectively). The skin-to-skin surgery time per THA was 34.5 ± 10.1 minutes for unilateral cases compared to 36.6 ± 9.9 minutes per procedure in a bilateral case ($P = .2$). Patient demographics and BMI did not correlate to the overall OR times ($P >$ .5).

The total OR time (mean patient in/out time and average turnover time) with associated costs are shown in Table 4. There was an average turnover time of 5 minutes. The total OR time for a bilateral case is 109.4 ± 19.8 minutes compared to 133.8 ± 12.8 minutes for 2 unilateral cases (66.9 minutes each case). This translates to an 18% reduction in the overall OR time when a single-staged bilateral THA is done. Table 4 shows that variable costs make up the largest portion of the procedure cost, indicating room for improvement. A resulting OR cost-saving of 14% (1356€ or $1379) per procedure was achieved. In 2019, the senior surgeon completed a total of 561 unilateral and 100 bilateral procedures. This was fit into an 8-hour OR day using the OR time determined in Table 5 and represents 124 OR days. We simulated the scenario where every bilateral procedure would have been replaced by 2 unilateral procedures. We calculated that this would require 129 OR days, as shown in Table 5. This demonstrates the lost opportunity of 5 additional OR days occupied to treat the same patient population. By applying the same logic, in 129 days, 35 more unilateral patients could have been treated, as is shown in the simulation of mixed cases in Table 5.

Discussion

Simultaneous bilateral THA is a safe procedure that can help address the projected increase in THA procedures over the next years. However, payment models need to incorporate incentives for surgical teams to motivate staff and hospitals while protecting the quality of care. This study has shown that a value-sharing model utilizing OR efficiency can be a solution to protect health-care costs and quality.

We found that a simultaneous bilateral procedure conducted with the EDA hip method was associated with a reduction in OR time and costs when compared to serial unilateral procedures. Our findings are in line with previous studies [11,12,14,16–19]. Furthermore, the EDA method applies a consistent and standardized process to performing THAs. When compared to other single-surgeon studies using the direct anterior approach, we report lower mean OR times of 135-140 minutes for bilateral procedures and 69-76 minutes for unilateral procedures [12,16]. We believe that this is mainly attributed to the efficiency measures that have been undertaken. First, an important cost and time reduction is obtained with the reduction of the instrument trays. This reduces the inventory volume but also the time to prepare each procedure. Second, orthostatic retraction tools such as the Gripper have been shown to reduce the number of staff required to conduct the procedure but also to impact the OR time by 17 minutes and reduce postoperative inflammatory response, which could be beneficial for bilateral THA procedures [22]. Third, single-stage bilateral draping allows for an efficient preparation time comparable to a unilateral THA procedure. Finally, the safety of using the same instruments for both sides is shown in our clinical data and adds to the time- and cost-efficiency.

The gains we report indicate that surgeon-driven initiatives to improve OR time and lower costs are highly impactful, especially with frequently performed procedures such as joint arthroplasties. While such improvements in efficiency have been studied largely in the area of total knee replacement [6], we believe our study shows an equally important advantage with THAs. Additionally, with our method of detailed timestamp capture, it is straightforward to determine which areas of the surgical process will provide the most benefits. Although variable costs comprise 90% of the cost for each procedure, which is the equivalent amount reimbursed by the Belgian government, we were able to reduce costs by 14% per procedure when performing 1 bilateral procedure over 2 unilateral staged procedures by reducing time-related costs. However, most payers do not incentivize surgeons for simultaneous bilateral THAs. The surgeon is compensated 50% less for the second side when

Table 5
The OR days for an 8-h OR day estimated from actual volumes of bilateral procedures performed in 2019 and time measured in the study along with associated surgeon fees.

Variable	Actual mixed cases	Simulation unilateral only	Simulation mixed cases
Procedure volume	661	761	696
Unilateral procedure volume	561	761	596
Bilateral procedure volume	100	0	100
Total implants	761	761	796
Total OR days	124	129	129
Total surgeon fees	319,950€ ($325,444)	342,450€ ($348,330)	335,700€ ($341,464)

A first simulation shows the number of OR days needed to treat the same patient population if only unilateral procedures are performed. A second simulation demonstrates the additional number of procedures that may be conducted with the extra days.
Values given both in Euro and United States Dollar as per currency Oct 2022 (1.00$ =1.02€).

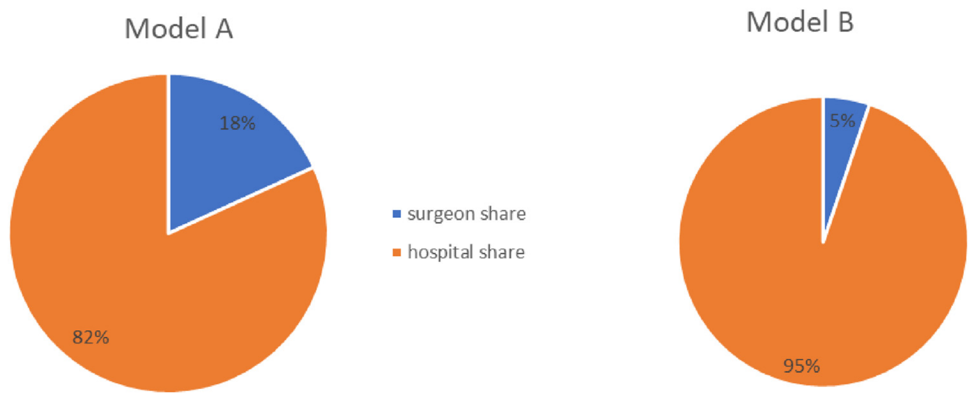

Figure 7. Value-sharing models show 2 possible models to split the cost-savings per case between the surgeon and hospital as a percentage of the total. In our example, this cost-saving is 1354€ ($1377). Model A: If the surgeon were compensated the same amount for bilateral cases as 2 unilateral cases, an 18% share of the value would be required. Model B: Due to the additional 5 OR days gained as shown in Table 2, the surgeon compensation amount would offset the loss to income with only 5% value-sharing needed with the hospital.

done simultaneously. This raises the question whether surgeon-driven initiatives are adequately rewarded. The issue of surgeon compensation in bilateral THAs was raised by Berend et al. [17] in their 2007 study in the United States but still remains unresolved to date. Based solely on the OR costs, we postulate that the hospital may consider applying a value-sharing system to better align incentives and further drive such improvement initiatives.

In our example, 2 major financial improvements were realized for the hospital. First, the OR cost is reduced by 14%, and second, additional OR days are gained. Specifically, in our simulation of the 2019 case mix (Table 5), the same number of hips would require 5 additional OR days to complete a series of unilateral cases. Although additional revenue may be generated for the hospital, from the surgeon's perspective, there is a significant loss in compensation. In our simulation, the surgeon obtains the most income when doing only unilateral cases where the compensation is 7% more than the actual case mix. Even with the added income from the additional OR days, doing only unilateral cases provides 2% more in compensation. Therefore, we propose a new value-sharing model (Fig. 7). In Figure 7, we show 2 models for value-sharing to account for this loss to the surgeon fee. Model A visualizes the obvious solution where the surgeon is compensated the equivalent of 2 unilateral cases. In our example, this is 18% of the cost-savings gained. In model B, we account for the income from the additional cases, and this requires only 5% of the cost-saving. These percentages will vary based on the specific reimbursement arrangements and case mix at each hospital. Our model shows that with a very small share of the value gained from improving the efficiency, the surgeon can be significantly incentivized rather than suffer a loss in compensation for choosing bilateral THAs when clinically indicated.

With the growing number of patients requiring THAs, hospital beds will become a limiting factor for how many patients can be treated. A bilateral patient will only be admitted once while unilateral patients will occupy a bed twice. This rationale may also be applied to the doubling of hospital admission overhead, surgeon consultation time, surgical room setup and breakdown, anesthesia, and post-operative physical therapy and rehabilitation. We sought to investigate how a surgeon-driven initiative may save time and cost and as such do not compare the overall treatment costs to the health-care systems of these procedures. However, several authors have reported lower overall treatment costs (including factors such as hospital length of stay) [13,14,17,19] when a simultaneous bilateral procedure is performed. While there are considerable economic implications of such findings to health-care systems, our experience demonstrates that the incentives to provide excellent patient care coupled with financial duty have not been aligned among national health-care systems, hospitals, and surgeons. This is echoed by studies conducted in the United States citing the heavy financial burden placed on the surgeon and hospital when electing to conduct bilateral procedures [14,17]. With time-driven cost models and systems such as bundled payments in the United States placing greater accountability on physicians and hospitals [10], we believe these incentives may be practically aligned with mutual benefits to all parties.

Our study is not without limitations. First, our sample size is relatively small. Due to the high consistency in the surgical process, this does not affect the outcome on OR cost or time and provides sufficient evidence to build a business case. However, further data-gathering may be warranted to take this topic further into discussion with national health-care systems. Second, our study was conducted by 1 surgeon who is very experienced in the surgical procedure. Therefore, the results may not be as applicable to surgeons who are still experiencing the learning curve. However, this is also an advantage as by eliminating surgeon bias, we were able to directly compare the unilateral procedures to the bilateral ones purely from the standpoint of the process. It would be interesting in further studies conducted to evaluate how this can translate to other hospital settings as well. Third, we do not have efficiency data prior to the implementation of the EDA in our practice. While this limits extrapolation of our findings to less-efficient settings, our findings are in line with the literature as well [13,14,17–19]. Fourth, patients that were selected for simultaneous bilateral THAs were on average younger, had a lower BMI, a lower American Society of Anesthesiologists score, and better preoperative PROM scores than patients who were planned for a staged bilateral THA. This might have created some selection bias. However, for the cases that were selected for the cost-efficiency analysis, there was no correlation between patient demographics and surgical time. Finally, as the study was conducted in Belgium, the variable costs were equivalent to the reimbursement provided by the Belgian government. We understand that this may not be fully transferable to other countries where reimbursement is often negotiated with payors and coming from a variety of sources. However, the goal of this study was to propose a value-sharing model which may drive further discussion with payors and health-care systems, and the proposed model can be adjusted to other reimbursement systems.

Conclusions

Performing EDA bilateral THAs provides surgeons and hospitals with a more-efficient and cost-effective solution when compared to performing serial direct anterior unilateral procedures. A value-sharing model should be considered to align incentives and avoid penalizing efficiency.

Conflicts of interest

A. Schreiber, C. Balust, A. Menon, and J. Dille are paid employees of DEO NV, C-Mine 12, 3600 Genk, Belgium. J. Dille has stock or stock options in DEO NV, C-Mine 12, 3600 Genk, Belgium. K. Corten receives royalties from, is in the speakers' bureau of or gave paid presentations for, is a paid and unpaid consultant for, receives research support as a principal investigator from, and receives financial or material support from DePuy-Synthes and MedEnvision and also has stock or stock options in MedEnvision.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.09.009.

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Appendix

Appendix A: Cost Data

Table A1
Variable costs are calculated or estimated from the sources listed.

Item	Source
Procedure-specific consumables	Prof. K. Corten, ZOL Hospital [1]
Forfait consumables	Estimated from FPS [2]
Procedure-specific drugs	NIHDI [3]
Anesthesiologist fee	NIHDI [3]
Surgeon fee	NIHDI [3]
Surgeon income	Prof. K. Corten, ZOL Hospital [1]
Implants	NIHDI [3]
Reusables sterilization	Tibesku et al. [4]

Table A2
Direct and indirect fixed costs are calculated or estimated from the sources listed.

Item	Source
Utilities and estate[a]	Estimated from Durant [5]
Equipment: maintenance and repair[a]	Estimated from Durant [5]
Equipment: depreciation[a]	Estimated from Durant [5]
Nonclinical support staff[b]	Estimated from Durant [5]
Clinical support (nurses)[b]	Derived
Head nurse	Estimated from KCE report [6]
Helper/support nurse	Estimated from KCE report [6]
Surgical team (no doctors)[b]	Derived
Circulating nurse	Estimated from KCE report [6]
Scrub nurse	Estimated from KCE report [6]
Anesthesiology nurse	Estimated from KCE report [6]
Helper/support nurse	Estimated from KCE report [6]
Assistant	Estimated from KCE report [6]

A fixed cost of 7.03€/min is calculated as a sum of the following costs for an 8-h workday at 90% OR utilization.
[a] Cost per OR.
[b] Cost of actual staff full time equivalent (FTE) across 10 ORs.

Derivation of cost per procedure

$$\text{Eq. A1}: \ \text{Cost per procedure} = \text{Variable cost per procedure} + \text{Fixed cost per procedure}$$

$$\text{Eq. A2}: \ \text{Variable cost per procedure} = \sum(\text{Variable unit cost} \times \text{Quantity})$$

$$\text{Eq. A3}: \ \text{Fixed cost per procedure} = \text{Fixed cost per minute} \times \text{Mean OR time}$$

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