Patient-factor stratification and its application in operative theatre management

Takayuki Kurokawa

Department of Traumatology and Orthopaedic Surgery
University of Szeged
6725, Szeged Semmelweis st. 6 / 2, Hungary

A dissertation submitted for the degree of Philosophiae Doctor

2024. October
Supervision by Prof. Dr. Endre Varga

List of publications

1. Kurokawa T., Kaneko Y., Mammen A.V., Walls V., Queiros I., Azaizah M., Bacon M., Török L., Varga E., **CASEMIX study: Assessment of patient factors influencing the subprocedure duration of trauma/orthopaedic surgeries**
   doi;https://www.injuryjournal.com/article/S0020-1383(24)00215-8/abstract
   Q1, IF; 2.2

2. Kurokawa Y, Kurokawa T, Fujii M, Tanifuji M, Nakajin T, Sato T, Machida I. **Proposal for a Simple Equation for Limb Muscle Weight Calculation.** Med Sci Monit. 2023 Feb 28;29:e938606. doi: 10.12659/MSM.938606. PMID: 36851828; PMCID: PMC9985304.
   Q2, IF; 2.2

3. Kurokawa T., Varga E. **Successful treatment of a challenging periprosthetic femoral fracture on a premenopausal patient with a long history of immunosuppression, MATROKPLAST,** 67. Edition, 2024. May. https://doi.org/10.21755/MTO.2024.067.0001.005

Abbreviations

ACL; Anterior Cruciate Ligament

AP: Anterior Posterior

ASA: American Society of Anesthesiologists

BMI: Body Mass Index

BW: Body Weight

CI; Confidence Interval

DM: Diabetes Mellitus

DXA: dual-energy X-ray absorptiometry

FW: total fat weight obtained by dual-energy X-ray absorptiometry

LMW: limb muscle weight obtained by DXA

HT: Hypertension

IOD: Intraoperative Duration

IQR; Interquartile Range

JLCA: Joint Line Convergence Angle

JRA: Juvenile Rheumatoid Arthritis

JSW: Joint Space Width

KL Classification: Kellgren-Lawrence Classification

LCP: Locking Compression Plate

LMWH: Low Molecular Weight Heparin

NOAC: New Oral Anticoagulants

OA: Osteoarthritis

ORIF: Open Reduction and Internal Fixation

PA: Posterior Anterior

PFHL: Proximal Femoral Hook Plate

RA: Rheumatoid Arthritis

SD: Standard Deviation

TAI: Thrombocyte Aggregation Inhibitor

TKA: Total Knee Arthroplasty

THA: Total Hip Arthroplasty

Introduction

"How long will my surgery take?" The best answer a surgeon can currently give is from a historical mean average for a particular procedure, considering how long surgery took for all patients, regardless of disparate diagnostic codes, demographics, surgeon experiences, comorbidities, and other risk factors. With so much diversity in procedure complexity, operation duration becomes inherently variable and inhibits robust and predictable planning.

The lack of productivity that follows is a significant barrier to the effectiveness of public healthcare systems in Europe. This is found not just in Hungary but in the United Kingdom, Austria, and more. Patient experience is poor with repeated cancellations and long waits. Experienced surgeons are left feeling underutilised where lists are underbooked. With the impact of COVID-19, it is estimated to take a typical country nearly one year (45 weeks) to clear their elective surgery backlog, even with a 20% increase in surgical activity over their baseline.[5] The mean cost of operating room (OR) time is $36 to $37 per minute, according to financial data from California's short-term general and speciality hospitals in the fiscal year of 2014.[6]

Our study is divided into two phases: phase 1, the surveying of general trauma and orthopaedic cases, and phase two; examining high volume surgeries, Total Knee Arthroplasties. By examining these two phases, we aim to identify the factors determining the intraoperative duration, while stratifying the patients' characteristics that may affect the intraoperative duration.

Furthermore, an important factor in understanding the patient's basic biometry, or rather its basics, is their Body Mass Index (BMI). Despite the fact that methods of diagnosis vary from measuring walking speeds and grip strength to radiological investigations, the majority of them have faced difficulties due to the myriad of tests or parameters required. [11,12] Diminished muscle volume can be diagnosed easily by radiological modalities such as computed tomography, magnetic resonance imaging, and/or dual-energy X-ray absorptiometry (DXA).

In orthopaedic surgery, quality of the bone is another factor that influences the outcome of the surgery and its postoperative outcome. Revision surgery is time-consuming and financially burdening as well, even in simple cases, but moreso in complex cases.[13]

While it still provides the necessary care to a patient in a cost-effectiveness perspective, it is still a rapidly burdening problem that must be addressed. [14,15] A better understanding of the status of the bony physiology can be further applied in surgery; operating osteoporotic patients have challenges that require extensive preparation and treatment strategy to avoid multiple revisions.

Aims

The aim of this series of studies is to provide a better understanding of factors that affect the surgical duration, especially those that are brought in by the patients. Those such as surgical instruments, surgeon experience, and surgical complexities have been known to prolong the duration of surgery, but a better understanding of patient factors definitely is required for efficient surgical suite management. .

We aimed to evaluate the relationships between patient characteristics and comorbidities, as well as surgeon experience and its relationship to intraoperative subprocedure duration. With a better understanding of these influential factors, our goal is to be able to identify the factors that largely influence surgical duration in certain surgical subprocedures.

Additionally, we assessed the statistical correlations between biometric values such as weight, height, upper arm subcutaneous fat thickness, and circumference and found a correlation with the values obtained by the patients' DXA scans, such as total Fat Weight (FW) and Limb Muscle Weight (LMW).

Materials and methods

Data for this monocentric study were prospectively acquired via real-time surveys from September 2020 to October 2022, in which TCC-CASEMIX® was utilized.

Every procedure, sub-procedure and risk factor was recorded according to its SNOMED CT definition and duration measured using TCC-CASEMIX®. This ensured consistency of clinical coding and high data usability. Pearson’s correlation tests were performed to evaluate the parametric values, whereas the means and standard deviations were examined in non-parametric values. Data analysis was performed in *MATLAB R2021a*.

Pre-operative data from 167 patients were acquired. Patients were excluded according to our exclusion criteria, a lack of complete preoperative data sets, and failure of measurement. In phase 1, we examined general trauma and orthopaedic patients to find correlations between data from pre-operative assessment with intraoperative duration.

Preoperative assessments included; age, height, weight, body mass index, and comorbidities. (Table 1) In phase 2 of the study we examined patients who received Total Knee Arthroplasties (TKA), focusing on high volume surgeries in depth.

Phase 1: wide spectrum survey of multiple surgeries.

The data acquisition tool acquired data for the study in two steps: Pre-operative Assessment (POAP) and peri/intraoperative measurement in a surgery data acquisition process (SDAP). In POAP, a 3rd party volunteer captures information about the patient (including age, sex, body mass index, and ethnicity), and enters each child sub-procedure (such as skin incision, reduction, and fixation). Independent clinical surveyors participated in the measurements of the surgeries.

Phase 2: Total Knee Arthroplasty

We largely grouped the detailed subprocedures into 3 major steps; 1. Skin incision to joint exposure, 2. Prosthetic implantation, 3. Wound Closure. Detailed subprocedures steps are described in the following:

While examined detailed subprocedure steps and its durations, we created macroscopic groups of the detailed subprocedures, facilitating the relationships between cohesive steps of TKA. (Figure 2) Joint Line Congruence Angle (JLCA) and medial and lateral Joint Space Width (JSW) were examined, and patients were categorized according to the Kellgren-Lawrence classification (from Grade 0 to Grade 4).

Our second study was conducted in accordance with the Helsinki declaration, and the study protocol was approved by the Ethics Review Board of Ebetsu Tanifuji Hospital. (Ethical Number R2-0910) One-hundred and nine patients were retrospectively examined for 33 months from July 2019 to April 2022. Data from 95 patients were utilized to discuss the correlation between physical parameters and the available values examined by DXA.

Measured physical parameters were body weight (kg), height (cm), upper arm subcutaneous fat thickness (mm) and upper arm circumference (cm) by use of caliper tools. Biometric data were measured according to protocols from the National Institute for Health Research to minimize personal bias.[16] FW and LMW of all four limbs were measured by

DXA using Lunar iDXA PRODIG (GE Healthcare, U.S.A.)[17] Statistical analysis was performed using JSTAT: Ver. 22.0E.[18] The Pearson's correlation coefficient and probability values were examined among physical parameters and the values obtained by the DXA. Probability less than 0.01 was regarded as significant.

Results

Phase 1 results: Trauma and Orthopaedic (General survey)

For each procedure in the TCC-CASEMIX® database, a benchmark of elapsed time broken down into productive and non-productive durations is provided. Productive time was defined as the viable time that was measured according to the designated subprocedure. In the majority of surgeries a significant amount of non-productive time was measured. For all procedures, 31.1% of operation duration was non-productive. The procedure with the highest amount of non-productive time was intramedullary nail screw-alignment insert (n = 3) with 50.5% non-productive. The lowest was 23.3% for open reduction and fixation (n = 25). Twenty-two sub-procedures had collected sufficient data to be statistically reliable (threshold: thirty sub-procedures). During the preoperative assessment, surgeons were asked to estimate the duration of sub-procedures. Generally, sub-procedure durations were overestimated by the operating team. Some sub-procedures were highly predictable: for example, the *application of dressing* (n = 165) had a standard deviation of 0.79 minutes, possibly explained by the simple nature of this procedure. Others were far less predictable, for example *fixation of fracture using screws* (n = 64) had a standard deviation of 12.14 minutes, likely as this is a complex procedure whose duration depends on the classification and severity of the fracture. Sub-procedure benchmarking was also completed for sub-procedures related to patient preparation.Just as with sub-procedures, the length of patient preparation activities was being overestimated significantly by the team. Each sub-procedure had a degree of variability, ranging from a standard deviation of 2.48 minutes for the *WHO Surgical Safety Checklist* (n = 171) to 1.36 minutes for *Application of Surgical Drapes* (n = 174).

The statistical analysis explored the relationship between surgeon experience and operation duration of *arthroscopy* (n = 29), finding a small deviation in elapsed time. For surgeons recorded with 8 – 9 years of experience, arthroscopies took an average of 37.75 minutes (n = 4) while for those with more than ten years of experience, arthroscopies took an average of 35.62 minutes (n = 19). The amount of non-productive time was also affected, at

34.1% for the 8 – 9 years of experience group and 32.9% for the 10+ years of experience group. Using statistical analysis to correlate risk factors with operation duration, it was possible to create cohorts of comparable patients with similar degrees of procedure complexity and operation duration.

Phase 2 results: Total Knee Arthroplasty (High Volume Surgery)

A total of 79 were studied and surveyed into TCC-CASEMIX©. Surgical steps were broken down into detailed subprocedures and also largely grouped into three major steps; skin incision to joint exposure (Exposure Time), prosthetic implantation (Implantation Time), and closure (Skin Closure Time). Total Duration (the time from when a patient arrives at the operation room until the end of the procedure) and Total Viable Time (the sum of each subprocedures in TKA). Individual factors were first assessed, followed by patient stratification, allowing us to find a pattern that contributes to better predicting intraoperative duration.

The mean age of the patient cohort was 67±17 years old. The correlation between age and Total Duration, Total Viable Time, Exposure Time, Implantation Time, and Skin Closure Time was examined. No significant correlation was found between age and IOD in each subprocedure. 76 patients' data were obtained out of 79 patients. The remaining 3 patients could not be evaluated due to missing patient data. The height of patients ranged from 146 cm to 190 cm, with the mean of 165.8 cm and the median of 165 cm. The weight of patients ranged from 47 kg to 126 kg, with the mean of 88.8 kg and the median of 88.0 kg. The BMI of patients ranged from 19.6 to 43.9, with the mean BMI of 32.3 and the median of 32.0. The BMI ranges were divided into 5 groups: less than 25 (n=9), 25 to 30 (n=12), 30 to 35 (n=31), 35 to 40 (n=18), and more than 40 (n=6). The correlation between height, weight, BMI, and the grouped sub procedures (Total Duration, Total Viable Time, Exposure Time, Implantation time, and Skin Closure Time) was examined. No significant correlation was observed between age and height and each subprocedure, whereas weight and BMI were minimally correlated.

Patient Comorbidities

We categorized patients into 5 groups, those who take Aspirin (n=12), Coumarin (n=4), Thrombocyte Aggregation Inhibitor (TAI) (n=2), New Oral Anticoagulant (NOAC) (n=4) and those who do not take any of anticoagulants (n=55). We measured the mean of Total Duration, Total Viable Time, Exposure Time, Implantation Time, Skin Closure Time, and time of haemorrhage control during the operation for each group. TAI had the most prolonged effect on total duration (118 min) and hemorrhage control (6.8 min), while compared to patients taking other anticoagulant therapy.

There were 61 patients with hypertension and 18 patients without hypertension. Hypertension was defined as the following; patients who were previously diagnosed with hypertension, and those who were taking antihypertensive medication. The presence of hypertension did not seem to drastically prolong the IOD. On the contrary, values were shortened minimally in the majority of subprocedures, except for Implantation Time. The presence of hypertension did not significantly prolong IOD. On the contrary, we found that values were slightly smaller in the majority of subprocedures except for Implantation Time, concluding this to be a factor that does not influence IOD.

19 diabetic patients and 60 non-diabetics were examined. Patients who were previously diagnosed with DM type 1 and 2, and those taking anti-diabetic therapy were included. To our surprise, patients with DM results in shorter Total Duration than non-diabetics (94.5 min and 100.5 min respectively), however the sample size for diabetics were significantly fewer, thus these results are inconclusive.

Degree of Osteoarthritis

We utilized the Kellgren Lawrence classification to evaluate the severity of osteoarthritis using five grades, Grade 0 to 4. There were zero patients with Grade 0 and 1. There were 3 patients with Grade 2, 17 patients with Grade 3, and 53 patients with Grade 4 (Total n=73). Of 79 patients, 6 patients' X- ray were not available. Results are presented in Table 10. Patients with more severe OA (Grade 4) had prolonged mean IOD. This suggests that the severity of OA has a minimal but prolonging impact on IOD in all patient groups. While Exposure Times and Skin Closure Times remained similar, Implantation Time slightly increased and therefore the Total Viable Time as well.

Moderate but steady prolongation of mean IODs was observed in patients with KL Grade 4 OA. This suggests that the severity of OA has a minimal but prolonging impact on

IOD in all patient groups. While exposure times and skin closure times remained similar, implantation time slightly increased, and consequently the total valid time as well.

1. Joint space width (JSW), Joint Line Convergence Angle (JLCA)

73 patients were examined with the KL classification as well as the JSW and JLCA, by knee AP/PA radiographs, to assess progression of knee osteoarthritis.

To measure the JSW, we measured the distance between the medial point of medial femoral condyle and articular surface of medial tibial condyle (M2), and the distance between the medial point of lateral femoral condyle and articularv surface of lateral tibial condyle (L1)

The distance of Medial and Lateral JSW ranged from 0 cm to 11.1 cm and from 1.4 cm to 13.5 cm, with the mean of 4.6±2.1 cm and 6.0±2.4 cm, respectively. To measure the JLCA, we measured the angle formed between two tangential lines at the distal femoral and proximal tibial articular surfaces. The JLCA of patients ranged from 0.7 degree to 20.4 degree with the mean of 5.4±3.6 degree. The correlations between Medial and Lateral JWS, JLCA, and Total Viable Time, Exposure Time, Implantation Time, and Skin Closure Time, and Total Duration were examined. Correlations between the Total Viable Time, Implantation Time and the lateral JSW were moderate, where JLCA, and mJSW did not show significant correlation in any of the subprocedures.

The differences between the different devices were also examined. 6 patients received Columbus (Aesculap, B. Braun), 39 patients received P.F.C. SIGMA (Johnson and Johnson), 34 patients received LEGION (Smith and Nephew) trays. Only Cruciate Retaining types were included for a unison comparison. The mean Total Viable Time of Aesculap was 73.4±14.3 minutes. The mean Total Viable Time for SIGMA was 69.3±13.0 minutes. The mean Total Viable Time for LEGION was 71.4±17.8 minutes.

Implantation Time was also examined (Figure 9), where Columbus took 37.9±15.2 minutes, LEGION coming in second at 35.9±11.5 minutes, and SIGMA at 35.6±7.7 minutes. In terms of Total Viable Time, Aesculap devices generally lead to the longest duration, whereas SIGMA from Johnson and Johnson the shortest. However, in the Implantation Time subgroup SIGMA from Johnson and Johnson seemed to bring the most consistent Implantation Time with small variance. Aesculap on the other hand, had the longest Implantation Time, with a high variance in the 4th quartile.

Patient Risk Stratification

By better understanding the impact of individual risk factors, we identified two major factors that affect surgical durations: BMI and surgeon experience. We organized different cohorts from 1 to 4 according to surgeons with less than 5 years of experience, and more than 10 years of experience, grouped with patients with BMIs of below or over 25, and 30. (Table 12)

The mean Total Viable Time for cohort 1 was 73.8±14.17 minutes, when in cohort 2 the mean increased to 115.3±18.35 minutes. Also, while comparing cohort 3 and 4, the mean time prolonged from 85.38 minutes to 104.15 minutes, indicating that while all surgeon groups were affected by the higher BMI of the patients, surgeons with less experience were affected even more, showing a significant role of BMI in prolonging IOD.

According to our risk stratification cohorts, we generated a data chart in which predicted times can be calculated according to the mean times and SDs of subprocedure times, as can be seen in table 13.

BMI as an index for patient factor stratification?

The gender distribution in the 95 cases was 27:68 for men and women, respectively. BMI, upper arm subcutaneous fat thickness, upper arm circumference etc was measured (Table 2) (mean ± standard deviation). Age ranged 47-102 years old (85 ± 8.3). Body weight (BW) ranged 26.8-64.0 kg (43.1 ± 8.17). Height ranged 134-175 cm (153 ± 8.85). Then BMI ranged 11.6-28.1 kg/m^2 (18.4 ± 3.18). Upper arm subcutaneous fat thickness was 0.6-18 mm (7.9 ± 4.0). Upper arm circumference was 12-27 cm (20 ± 3.0). Measured parameters by DXA were as follows; FW was 3563-25823 g (11823 ± 5203.9) and LMW was 6951-17595 g (10772 ± 2388.2). Upper arm subcutaneous fat thickness had significant correlations with BMI ($P < 0.001$) and FW ($P < 0.001$). Upper arm circumference also had significant correlations with BMI ($P < 0.001$) and FW ($P < 0.001$). On the contrary, upper arm subcutaneous fat thickness had no correlation with LMW ($P = 0.163$) Upper arm circumference showed correlation with LMW but with low r (0.458).

Figure 10. Statistical analysis for each Correlations, that Total Fat Weight (FW) obtained by DXA strongly correrates with BMI.

Since upper arm subcutaneous fat thickness and circumference did not significantly correlate with LMW but do with FW, we tested the correlation between BMI and FW. Then we found that BMI significantly correlates with FW ($r = 0.823$, $P< 0.001$) as can be seen in Fig. 11. The linear correlation suggests that BMI can mathematically substitute FW. Therefore, we additionally hypothesized that there may be a correlation between LMW and the difference of BW and BMI (BW - BMI) . As a result, LMW significantly correlated with BW – BMI ($r = 0.719$, $P < 0.001$). Consequently, we can regard BW - BMI as muscle mass which might help to presume harboring muscle mass (Fig. 12).

Special case and considerations; Osteoporosis

Osteoporotic patients pose a particular difficulty when brought into the operating theater. Not only do the quality affect the biomechanics of the surgery, but the follow-up ups post-operative rehabilitation programs may also differ when compared with a non-osteoporotic patient. Moreover, the risk of revision surgery may also burden the patient and the surgical team with additional costs and IOD.

Here we present a case of a 39 year old female patient with a 30 year history of immunosuppression (4 mg of methylprednisolone) due to Juvenile Rheumatoid Arthritis (JRA) from the age of 8. By the time of admission at our clinic, the patient had already undergone right side Total Hip Arthroplasty (THP) in 2010, left side total knee arthroplasty (TKE) in 2011 and right side THP in 2013. Her acute postoperative course was uneventful. In June 2019, the patient presented with pain and discomfort in her right thigh during physiotherapy. She was admitted to her local Traumatology department and was diagnosed with a right side femoral shaft fracture of which was surgically reduced by Open Reduction and Internal Fixation (ORIF) with plates. In October 2019, the patient again presented with spontaneous pain in her right thigh. She was then diagnosed with a Vancouver C type periprosthetic fracture on the right femur, and was referred and admitted to our level one Trauma center in Szeged, Hungary. The patient received a Locking Compression Plate (LCP) type Proximal Femoral Hook Plate (PFHP) with attachments and a bone autograft to reinforce stability and neutralize stress on the fractured area. By 2020.02.04 (111th postoperative day), the patient was able to complete weight bearing on the operated limb. In 2020.06.25. the patient presented again to our outpatient clinic with pain in her operated right hip, while playing with her children. Radiology revealed that the right LCP-PFHP component had been fractured. We surgically exchanged the LCP PFHP and further added a cadaver

allograft component to the fractured area in hope of increased ossification. Cable fixation was utilized the stabilization of the allograft, as well as the distal end of the LCP-PFHP, and completed a allograft strut osteosynthesis, The patient was observed post-operatively on our ward, with no unusual findings radiographically.

Discussion

General considerations

Discussing procedure benchmarks in further detail, the results are plausible and verify the relationships between risk factors, procedure complexity and operation duration found in literature.[19] Arthroscopies are typically a short, high-volume procedure performed by a surgeon, but there was a large difference between the surgeon's own estimates and the actual operation duration. In a survey, it can be difficult for a single surgeon to estimate the time required for a partial or full surgical procedure.[20] Likewise, risk factor analysis demonstrated that operation duration variability was greatly reduced when estimations were taken from cohorts of patients with similar degrees of procedure complexity, as identified by the algorithm. Compared to the surgeons' own estimates of operation duration which overestimated significantly, more reliable prediction was possible for arthroscopy using the algorithm. In fact, there are similar studies for using machine learning approach to predict IOD, which resulted in the higher predictive capability compared to surgeons' own estimation. [21]

On the other hand, open reductions and fixation procedures depended heavily on the presentation and classification of the fracture. Indeed, the operation duration depends more on the fracture being treated than patient risk factors, even where disparate, as evidenced by their being no clear correlations in the risk factors unlike for other procedures. Hence, as the surgeon has received an X-ray and other diagnostics of the fracture by the time of preoperative assessment, an accurate estimation of duration should be possible, but without controlling for fracture presentation in the study, meant that the risk factor cohorts found for arthroscopies were not observable for this procedure.

Total Knee Arthroplasty is a common procedure, which has been successful and developed through many studies around the world for over 50 years.[22] In this prospective real

time analysis of high volume TKA surgeries, we discovered that the IOD was impacted by more than one individual factor, namely BMI, Degree of OA, and experience of the operating surgeon. These factors, though individual only moderately correlated to the prolonging of IOD; prolonging IOD in subprocedure steps such as prosthetic implantation and skin closure, therefore prolonging the duration of the entire surgery. The IOD of younger surgeons with less than 5 years of experience were drastically affected by the patients BMI, showing over 20 minutes of extra time in stratified groups, which could lead not just to the delay of the surgical program, but the increase in postoperative infections.[24] While an increase in surgical time of only 15 min leads to 13% higher chances of surgical site infection, most orthopedic prosthetic implantation surgeries last for more than an hour.[25] It also known that prolonged operative duration leads to more complications and the reduction of IOD is of crucial importance especially in high volume surgeries and should be a "Universal Goal".[26]

In contrast to some opinions saying that surgeries are highly unpredictable, the use of machine learning models and predictive models have brought fruitful results in predicting total surgical duration.[27] Information on pre-operative assessment and its effects on detailed subprocedure duration is sparse, and through our study we have well understood that certain factors such as BMI and surgeon experience impact subprocedures like prosthetic implantation stage dramatically. We also claim that in high volume surgeries, predictability can be refined, and should be encouraged to be used in regular operating theater planning.

The complete breakdown of subprocedures show that the younger surgeons tend to have major problems in the prosthetic implantation steps, and tend to be slower in wound closures. The differences between younger surgeons and experienced surgeons considering the skin incision until joint exposure step were minimal. This seems to be a partially contradictory finding, where other studies have claimed that surgical exposure times differed significantly in non-high volume patients, especially in patients with high BMI.[28] While examining the correlation between the individual steps and BMI, we found moderate correlation. When we included the surgeon's experience to the analysis, we suspected that the IOD of younger surgeons who operated on higher BMI patients were significantly prolonged, by over 42 minutes on average. This pattern was similarly observed in experienced surgeons, where the mean duration was prolonged by 19 minutes. Since patients usually present with KL grade 3 or 4 arthritis for a TKA procedure, minimal correlation was observed while considering the degree of OA and IOT. Other studies also indicated BMI and ASA may contribute to surgical duration prolongation, its conclusions widely vary. [29] The use of BMI

seems to be questionable, and though it seems to add some insight, its use alone should not be encouraged, but should always be part stratified cohort, for it to be a reliable predictor.

Radiological evaluation of OA, while an essential step in preoperative planning, seems to have minimal to moderate correlation with IOD, even with symptomatic relief and functional improvement.[30] The JLCA, which provides information of the degree of varus deformities, had no significant correlation during the prosthetic implantation step, which was a contradictory finding to some studies.[31] While the Lateral JWS seemed to impact the implantation time, its correlation seemed minimal (p=0.313) The correlation between mJWS and the intraoperative durations were practically non-existent, which could be due to the fact in progressive osteoarthritis, the mJSW is non-existent because of the bony surfaces contacting on each other.

The reliability of BMI as an index?

The human body consists of many different constituents such as hard and heavy minerals, water-rich muscle, and relatively light but large amounts of fat, making it rather heterogeneous. Ancel Keys et al. had provided an idea that the amount of harboring body fat could be correlated with the patient's BMI.[33] In contrast to its wide use, BMI has been criticized for not containing relevant information about the patient, such as fat mass and others BMI also does not take into consideration a wide variety of factors such as ethnicity, sex, and age, giving only a poor idea of the individual's body composition, and with it, the underlying comorbidities.[34, 35]

While the gold standard of diagnosing muscle mass seems to be unchallenged, emerging modalities have been identified to be useful in the identification of muscle mass, but with certain difficulties.[36] Although ethnical and disease-specific modifications apply, the accuracy of DXA have been backed by numerous literature.[37] The radiological measurement to obtain accurate values requires special equipment and qualifications, rather than cheaper and lighter devices such as impedance adipometry and ultrasonic measurement of muscle thickness.[38, 39]

Understanding the correlation between BMI and FW

While literature examining the relationship between BMI and FW is relatively rich, these studies mainly focus on either younger patient populations or have been focused on

osteoporosis. Still, the estimation of body composition without the use of radiological and biochemical methods seems to be challenging.

Our study showed significant correlations between FW and upper arm subcutaneous fat thickness and/or circumference. More importantly, BMI had a significant correlation with FW. These findings seem to be well received in international literature, especially when measured by impedance adipometry or DXA.[42] MW // BW - BMI would then theoretically represent muscle mass.

Upon understanding this dynamic relationship between the values of MW, BW, and BMI, we re-examined the correlations between these parameters, and found that LMW is significantly correlated with BW - BMI. From this correlation we devised an equation; 289.2 x (BW - BMI) + 3631, which could be applied as a relative index to identify underlying muscle mass. In Fig. 3 we see a large portion of patients' LMW indicating low muscle mass. Even when BMI offered no information on sarcopenia in these patients, the results of the SMW showed that most patients were sarcopenic. On the other hand, patients with low BMI did not necessarily show low LMW, as can be seen in Fig. 4. High BMI did not necessarily mean that the patients did not have diminished muscle mass; some patients with relatively high BMI even presented with low LMW.

Managing the Operating Theater applying stratifying patient factors

Managing an operating theater may be a controversial task. While surgeons think that surgery must not be done with haste, data on its prolonged duration has proved otherwise. With increased risk of infection, financial burdens, and environmental problems surrounding the discussion of surgical suite management, our series of research aims to identify the most prominent factors that may affect the IOD, and therefore those consequences. BMI had been a major factor affecting surgical duration, but its overuse seems to be questionable. BMI, is a body index that contains no information on the individual; fat, muscle, and bone quality cannot be identified or quantified. This would mean that an obese person and a muscular person would be registered as a "similar body type". In our research BMI was also a predominant factor affecting IOD alongside surgeon experience. The interpretation of these results with BMI should be done with care, as it does not reflect the fat content nor the lean muscle mass of the subject patient. BMI as an index should be used with caution, since it may be the undesirably high fat content and low lean muscle mass that may lead to perioperative/intraoperative complications. Even in studies by Woon et al. utilize BMI as a

measure of obesity and have concluded that obese patients have shorter hospital stays and higher home discharge rates.[57] Without the knowledge of body constituents, it is as if the presence of free fat can have a positive outcome to the postoperative condition of the patient, which can be misleading. A study by Stevens-Lapsley et al also found that BMI had no correlation with the postoperative functional outcome, which may also be translated to the following; BMI as an index does not contain functional information of the patient.[58] Hwang et al have found in a retrospective study that low lean muscle mass, namely sarcopenia is a crucial factor for postoperative complications such as anemia, delirium and acute kidney injury. [59] Evidence surrounding the opaque use of BMI as a unit for individual body composition may not necessary support the application of it even in peri-operative planning.

The incorporation of stratified patient factors may also lead to prevention of revision surgery. While others focus on the selection of implants and techniques in trauma related surgeries, we advise to also pay attention to patient factors, and its possible incorporation in the pre-operative preparation process.[60] Revision surgeries, with its complex nature in itself, may be costly and time consuming to handle, and a myriad of methods should be invested to avoid it. [61,62] Other large scale strategies such as the national registries seem to also have a positive effect on reducing the proportion of revision procedures.[63]

Implication in device registration and others

Using an independent and flexible cloud registry system, we have also registered surgical devices, and its respective carbon emissions. By understanding the differences in subprocedure duration between different devices in detailed subprocedures, we can assign surgical devices to the fitting of the patient and the surgeon. No longer will this be only a question of personal preference, but a decision based on objective quantitative data. For example, younger surgeons will obviously benefit from operating on patients with relatively lower BMI (<30) while experienced surgeons could be encouraged to operate on patients with high BMI to maximize the use of the operating theaters.

With device registry as an additional function, we can evaluate the devices' performances which "fit" patient characteristics and other factors. More importantly, we can now "follow" the devices through the network, creating a virtual database containing all relevant information that we are able to cross analyze the data across hospitals, and ethnicities.

Conclusion

Patient factors such as high BMI and osteoporosis can drastically alter the design of surgical suite management. Patient biometrics and years of surgeon experience are significant factors when predicting IOD. Surgical durations are moderately affected by the BMI of patients, but those with less experience are markedly affected by the BMI of the patients, prolonging their IOD mostly at the level of prosthetic implantation phase. Patient stratification according to BMI and years of surgeon experience were the greatest predictors of intraoperative duration. Non-parametric factors like history of smoking, presence of HT or DM, use of anticoagulants showed minimal or no correlation with IOD prolongation. Degree of OA do not seem to significantly alter the IOD in TKAs. Although BMI was one of the leading patient factors affecting IOD, it is also crucial to point out that BMI in itself does not include any information considering patient body constituents, and may possible lead to a misinterpretation of the data acquired. While BMI can also serve as an indicator of patient status to calculate muscle mass at a screening level with the use of DXA as well. A multidisciplinary perioperative planning is necessary to ensure a successful postoperative course in order to minimize revision surgery.