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The use of damage control orthopaedics to minimize negative sequelae of surgery delay in elderly comorbid patients with hip fracture

C.-H. DONG, Z.-M. WANG, X.-L. ZHAO, A.-M. WANG

Department of Orthopedics, Institute of Surgery Research, Daping Hospital, Third Military Medical University, Chongqing, China

Z.-M. Wang This author contributed equally to this study and share first authroship

Abstract. – Hip surgeries count to the most frequent orthopaedic operations in older patients. Nonelective surgeries for hip fractures cause substantial economic burden because of high costs of medical treatment and high associated mortality. Surgery for hip fracture in the elderly comorbid patient still presents a challenge to orthopaedic surgeons. It is recommended that this surgery is performed within 48 hours after sustaining the hip fracture to decrease mortality. Yet the recommended early surgery (i.e. 48 hours after the incident) is not always feasible due to the frequent overall frailty of the patients or conditions of concomitant disease. The care of patients unfit for early surgery has been not adequately addressed in the literature. We have previously introduced an algorithm based on ASA-PS and P-POSSUM scores to stratify elderly comorbid patients for early vs delayed hip surgery, and used principles of Damage Control Orthopaedics to minimized negative sequelae of surgery delay (Dong C et al., PLoS One 2016). In this paper, we elaborate on Damage Control Orthopaedics and the proposed approach in the context of frequent comorbidities in the elderly orthopaedic patients. Further studies on this subject are urgently needed to establish international consensus on hip fracture surgery delayed due to overall patient frailty or extensive comorbidities.

Key Words:
Hip fracture, Elderly, Older patient, Frail, Damage control orthopaedics, Surgery, ASA, P-POSSUM, Comorbidity, Algorithm.

Introduction

Hip surgeries count to the most frequent orthopaedic operations in older patients. Many of these surgeries are conducted as elective surgeries (e.g. total hip arthroplasty due to osteoarthritis). Unlike some 50 years ago[1], elective hip orthopaedic surgeries are now considered a safe procedure even for octogenarians[2]. However, there is a substantial number of hip surgeries conducted as part of urgent intervention such as to remedy a hip fracture. The latter surgeries can pose significant challenges for the treating physician.

Hip fractures cause substantial economic burden due to high costs of medical treatment and high associated mortality[3]. It is estimated that the costs associated with the treatment of these patients are as high as $10 billion per annum in the USA[4]. Treatment optimization will help to reduce these marked costs and decrease mortality.

Hip fractures are significantly associated with older age[5]. With patients' advanced age, comorbidities, and frequent frailty, it is essential to conduct a proper pre-surgery risk assessment to determine the timing of the surgery and adequate postoperative measures. Complications are common in elderly orthopaedic patients[6], and preoperative risk assessment and timing of the surgery are key elements for the success of this operation.

There are few literature reports discussing the timing of orthopaedic surgeries for hip fracture with the specific focus on the elderly. The very recent Clinical Practice Guideline by the American Academy of Orthopaedic Surgeons Board of Directors [7] has recommended carrying out the surgery within 48 hours after hip fracture to reduce mortality. The level of evidence to support this was stated as "moderate strength"[7]. In addition, the Guideline has not indicated what to do if early surgery is not feasible (more ill patients)[7]. This needs further discussions on this subject.

We have recently published a study on stratification of comorbid hip fracture patients into early surgery and postponed surgery[8]. In those with postponed surgery, we have further devised diagnostic algorithm, conservative treatment measures and evaluations to improve the patient's suitability for hip surgery. We

Corresponding Author: Ai-Min Wang, MD; e-mail: trauma2@163.com

have demonstrated that it is feasible to postpone the surgery to stabilize the patient's condition without a significant increase in mortality if Damage Control Orthopaedics principles are applied[8]. In this review, we will address important determinants of the success of the surgery for hip fracture in older patients, including those with comorbidities. Specifically, we will highlight perioperative assessment and management, and application of the principals of Damage Control Orthopaedics as essential elements for successful orthopaedic surgery.

Health Status in Older Patients and its Pertinence to hip Fractures

Older age is the recognized risk factor for hip fractures[9,10]. The relative proportion of older people (> 65 years old) has dramatically increased in developed countries and is steadily increasing in developing countries. The statistics from the USA demonstrate that percentage of older people has reached 14.1% of the general population in 2013 and is expected to increase to 21.7% by 2040 (http://www.aoa.acl.gov/aging_statistics/index.aspx). In Japan, the proportion of the elderly has been reported to have increased four times from the 1950s[11], with the similar, albeit less dramatic trend seen in Germany [12] and other developed countries.

Geriatric definitions generally distinguish between "young old", "old", and "old old" age (respectively, 64-74, 75-84 and 85 and higher years old), although definitions vary somewhat between sources[11,13,14]. This is because person's ability to handle everyday's tasks changes progressively through these years, from normal to diminished. But it should be emphasized that in defiance of dire statistics and definitions, many older adults are still in a better health that their parent generation used to be at the same age. This is because many jobs are less taxing or physically demanding that they used to be before, as well as because of better awareness of the importance of healthy lifestyle and diet, and advances in modern medicine and pharmaceutical therapies. Therefore, the ability of a particular patient to undergo the surgery for hip fracture should not be judged based on the age alone. Rather, all primary and secondary determinants (age, comorbidities, other relevant health parameters) should be thoroughly considered when planning the surgery. Some of these comorbidities will be highlighted in this subsection in relationship to the assessment of the surgical risk in patients with hip fractures.

Due to our sedentary lifestyles and overeating, the prevalence of people with excessive weight and diabetes mellitus is increasing in developed societies. Other consequences of age- and life-style related changes relevant to hip fractures and orthopaedic surgery include comorbidities (cardiovascular disease, cancers, chronic obstructive pulmonary disease, weaker immune system) and longer tissue repair processes due to advanced age. These are the factors that indirectly influence the propensity to hip fractures, hip surgery, or post-surgery recovery. There are comprehensive reviews on this topic, and we refer the reader to consult these reviews for further detail[15-17].

Instead, we will discuss health conditions that develop in older patients and directly determine hip orthopaedic surgeries, both elective or due to incident fractures. These conditions are osteoarthritis, rheumatoid arthritis, osteoporosis, physical characteristics (e.g. muscle strength), mental health or use of anti psycotropic drugs, Parkinson's disease, and smoking.

Osteoarthritis of the hip joint is the main indication for elective hip surgery, and more than three-quarters of patients are elderly[18]. The reports from the USA estimate the prevalence of osteoarthritis at nearly 10%[19,20], both in general and older populations. Notably in China, the corresponding number is substantially lower[21]. The association between hip osteoarthritis and propensity to hip fractures remain unclear and controversial[22-24]. At the moment, it can only be concluded that hip osteoarthritis is the proven determinant of elective hip surgery, whereas firm evidence of similar association to hip fracture is still lacking.

In contrast, rheumatoid arthritis significantly increases the risk of hip fractures[25-28]. This discrepancy may be the consequence of differences in pathogenesis between rheumatoid arthritis and osteoarthritis. The differences between both diseases are highlighted by the fact that the genes that are respectively modulated by either disease are mostly non-overlapping[29]. The association between rheumatoid arthritis and hip fractures is likely through osteoporosis, which frequently develops as a comorbidity in rheumatic arthritis[30]. It is not clear whether this is related to the use of corticosteroids[28]. In China, the prevalence of rheumatoid arthritis involving the hip joint is lower than in the West[31,32]. However, Chinese patients may have a higher propensity for developing osteoporosis as a consequence of rheumatoid arthritis[33], which increases the risk of incident fracture.

Osteoporosis is the major and recognized risk factor for hip fractures. Many affected individuals at elevated risk are underrecognized and not properly treated[34]. Subsequently, many of these underrecognized patients with osteoporosis develop hip fractures[35], specifically the low-energy fractures caused by a fall from a standing height or a lower height. Conversely, the treatment of osteoporosis diminishes this risk[36]. Osteoporosis is believed to be more frequent in elderly women as a result of postmenstrual hormonal changes[37]. Coherent with this, hip fractures are also more frequent in female patients[5,37].

Individual physical characteristics, such as muscular strength, height, or body-mass index also contribute to the risk of a hip fracture[9,38-40]. In fact, studies have even coined a term "faller" or "recurrent faller"[41,42] to describe those whose physical characteristics appear to predispose them to low-energy falls and subsequent hip fractures.

Dementia[43-46], as well as the use of psychotropic drugs[47], are recognized risk factors for hip fractures in the elderly, especially those residing in the long-term care facilities[44]. Elevated risk is due to a higher propensity to falls, as well as increased prevalence of osteoporosis in patients with dementia[48]. These two factors are also the contributors to hip fractures in patients with Parkinson's disease[49], as this disease is known to be significantly associated with hip fractures[10,49-52].

Cigarette smoking increases the risk of hip fracture[53,54], most likely by promoting osteoporosis[55]. Importantly, the osteoporosis-promoting effects of cigarette smoking are unrelated to gender[54]. In addition to increasing the risk of hip fracture, cigarette smoking also promotes other skeletal fractures in older people[56].

While the aforementioned factors are determinants of the risk to develop hip fractures following low-energy falls, there are also other factors that determine patients' ability to undergo orthopaedic treatment. These also determine how soon the surgery can be applied. In the next subsection, we will discuss some systems to score the patients based on their overall condition and comorbidities. We will then propose the strategies of patient stratification for early vs. delayed surgery, and how to improve the outcome in those with delayed surgery.

Scoring Systems to Assessment of Patient's Overall Condition and Comorbidities

Older patients are frequently comorbid. Thus, in addition to diseases and conditions highlighted in the previous subsection, there will be other diseases that can affect patient's condition and determine the timing of the surgery. Given this, there have been attempts to combine both the details pertinent to the hip fracture and the parameters describing the overall patient condition (including comorbidities).

The overall assessment of patient's condition can be done using the American Society of Anesthesiology Physical Status (ASA-PS) score[57-59]. Based on patient's condition, this score ranks the risk from class 1 through 6 (Table I). It is estimated that 81% of surgeries are currently performed in patients of 55 years of age or over[12], and that these patients comprise the ASA-PS classes III and IV. This score is easy to use and is widely recognized. The disadvantage of this scoring system is that it does not assess the specific condition (i.e. hip fracture) and is quite subjective, relying on physician's experience and qualification.

Table I. The American Society of Anestesiologists Physical Status Classification System.

American Society of Anesthesiologists Physical Status (ASA-PS) score	Definition	Additions
ASA I	A normal healthy patient	Addition of "E" denotes "Emergency"[#] surgery
ASA II	A patient with mild systemic disease	
ASA III	A patient with severe systemic disease[*]	
ASA IV	A patient with severe systemic disease that is a constant threat to life	
ASA V	A moribund patient who is not expected to survive without the operation	
ASA VI	A declared brain-dead patient whose organs are being removed for donor purposes	

Footnote: Modified from the ASA-PS score (https://www.asahq.org/resources/clinical-information/asa-physical-status-classification-system). [*]Literature reports indicate that over 80% of patients ranked as ASA-PS III-IV are older patients (reference 12). [#]The ASA defines "Emergency" as "existing when delay in treatment of the patient would lead to a significant increase in the threat to life or body part" (https://www.asahq.org/resources/clinical-information/asa-physical-status-classification-system).

Table II. The Nottingham Hip Fracture Score.

Factor		Score
Age	66-85 years	3
	> 85 years	4
Gender	Male	1
AMTS*	< 7	1
Admission Hb#	< 100 g/L	1
Residence	Living in a long-term care facility	1
Comorbidities	≥ 2	1
Malignancy		No = 0 / Yes = 1
	Total	**Max 10**

Footnote: Modified from the Nottingham Hip Fracture Score (reference 60). The score is used in a regression analysis formula to calculate the mortality risk. There is a smartphone app (https://itunes.apple.com/gb/app/nottingham-hip-fracture-score/id587776442?mt=8) that can be used to calculate the mortality risk. Alternatively, the cutoff of ≥ 6 identifies patients at high risk of postoperative death (reference 60). *AMTS: Abbreviated Mental Test Score; this is the British analogue of the North American Mini-Mental Test Score; the interchangeability of both cognitive test scores for hip surgery risk calculation is unclear. #Hb: hemoglobin.

Therefore, a more hip fracture-specific score has been suggested. It is called the Nottingham Hip Fracture Score (Table II;[60]), and it identifies patients of high short-term (30 days) postoperative mortality risk. Various factors have been ranked based on the understanding of their relative contributions to the mortality risk. The factors are then added to yield a score, which is then used to calculate the risk using a regression analysis formula[60]. The formula has been slightly revised in 2012 and 2015, and a smartphone app has been developed to calculate this score (Table II). Alternatively, the cut-off of ≥ 6 was proposed to identify patients at high mortality risk after the surgery[61]. The disadvantage of this score, in our view, is that it is not detailed enough in the part accessing comorbidities. Thereby, comorbidities receive relatively low merit in the final score. Nonetheless, this score has been shown to have good predicting power for estimating immediate and long-term postoperative mortality. In addition, no score will be comprehensive enough to cover all potential determinants of the surgery outcome in elderly patients with hip fracture. This can be overcome by the use of a combination of two different scores.

In this regard, we have gotten good experience with another frequently used score called P-POSSUM (The Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity score) (Table III;[62]). The P-POSSUM score utilizes 12 physiological parameters and 6 operative parameters (Table III). Each parameter can be entered as several different items and, depending on the item entered, receives a score from 1 through 8. The scores are then used in the formula to calculate predicated morbidity and mortality. These two are calculated as per cent.

The drawback of this score is that it overestimates the surgery risk in low-risk patients, and the developers of this score freely admit to this overestimation (http://www.riskprediction.org.uk/pp-index.php). Another drawback is that the score requires intraoperative data for calculations. Some users claim that P-POSSUM is thereby less suitable for preoperative assessments [63]. However, we will demonstrate in the subsequent text how we enter "Operative Parameters" to override this and to calculate the score before the surgery.

There also exist alternative scoring systems, and we refer the reader to published reviews on this subject[17,64,65]. As mentioned previously, there is probably no ideal scoring system, and a combination of two or more scoring systems will help to make the risk estimate and patient stratification less biased. In our recent publication[8], we have used the ASA-PS and P-POSSUM scores. Those suitable for early surgery (i.e. within 48 hours) have received the surgery within this time frame. In other patients, conservative measures have been utilized to improve their condition and to enable the surgery. We will describe in subsequent subsections how we have combined patient stratification with the principles of Damage Control Orthopaedics to minimize adverse effects of surgery delay.

Early vs. Delayed Surgery: the Use of Damage Control Orthopaedics to Most Optimally Prepare for Delayed Surgeries

In patients with hip fractures, delaying the surgery beyond 48 hours post-incident markedly rais-

Table III. The physiological and operative severity score for the enumeration of mortality and morbidity (P-POSSUM) score.

A. Physiological parameters	Variables
Age	• < 61 years old • 61-70 years old • > 70 years old
Cardiac	• No cardiac failure • Diuretic, digoxin, anti-anginal or anti-hypertensive medication • Peripheral oedema, warfarin, borderline cardiomyopathy • Raised JVR*, cardiomegaly
Respiratory	• No dyspnoea • Dyspnoea on exertion, mild COAD# • Limiting dyspnoea, moderate COAD • Dyspnoea at rest, pulmonary fibrosis/consolidation on X-ray
ECG	• Normal • AF&, rate 60-90 • Any other abnormal rhythm, ectopics > 4 per min, Q waves, ST/T changes
Systolic blood pressure, mm Hb	• 110-130 • 100-109 or 131-170 • > 170 or 90-99 • < 90 mm
Pulse rate, beats per minute	• 50-80 • 40-49 or 81-100 • 101-120 • < 40 or > 120
Haemoglobin, g/dL	• 13-16 • 11.5-12.9 or 16.1-17 • 10-11.4 or 17.1-18 • < 10 or > 18
White blood cells count, × 10^{12}/L	• 4-10 • 10.1-20 or 3.1-4 • > 20 or < 4
Blood urea, mmol/L	• < 7.6 • 7.6-10 • 10.1-15 • >15
Sodium, mmol/L	• 135 • 131-135 • 126-130 • < 126
Potassium, mmol/L	• 3.5-5 • 3.2-3.4 or 5.1-5.3 • 2.9-3.1 or 5.4-5.9 • < 2.9 or > 5.9
GCS$	• 15 • 12-14 • 9-11 • < 9

Table continued

Table III. *Continued.* The physiological and operative severity score for the enumeration of mortality and morbidity (P-POSSUM) score.

B. Operative parameters	Variables
Operation type	• Minor operation • Moderate operation • Major operation • Complex major operation
Number of procedures	• 1 • 2 • > 2
Operative blood loss, ml	• < 100 • 101-500 • 501-999 • > 1000
Peroneal contamination	• No soiling • Minor soiling • Local pus • Free bowel content, pus or blood
Malignancy status	• Not malignant • Primary malignancy only • Malignancy + nodal metastases • Malignancy + distant metastases
CEPOD¶	• Elective • Urgent/emergency • Emergency (within 2 hours)

es the short- and long-term mortality[66]. Therefore, the recent Guideline has emphasized the need for conducting the surgery within this time frame[7]. Simultaneously, this Guideline has indicated that physicians should "be sensitive to patient preferences"[7]. In this regard, it can be pointed out that the Guideline does not provide a detailed recommendation on how to deal with elderly, frail or comorbid patients, whose overall condition does not allow the surgery within the optimal time frame. This is where we believe the Damage Control Orthopaedics principles are very useful.

The term "Damage Control" has been borrowed from the military vernacular. Originating in the World War II, this term has defined the complex of measures aimed at containing the damage cause by enemy fire to a navy vessel. The ship was to be protected from spreading fire, and flooding was to be stopped to keep the vessel afloat until it was tugged to the home port for more extensive repairs.

The Damage Control Orthopaedics aims at containing and stabilizing the orthopaedic injury until the patient condition will improve to warrant better surgery outcome. The rationale behind avoiding immediate surgery is to minimize adverse effects of the surgery. In the 1980s, the concept of the "two-hit model" has evolved, with the first "hit" being the injury and the second "hit" being the stress and adverse effects related to the surgery[67]. According to this concept, the first, injury-associated "hit" causes a less extensive systemic inflammatory reaction, whereas the "second" post-surgery hit is much more massive[68]. This calls for delaying the surgery until patient's condition has stabilized and most "priming" effects of the first "hit" will subside. This concept was most frequently applied to polytrauma patients[69], as well as to military personnel sustaining orthopaedic injuries on a battle field[70]. We have applied the Damage Control Orthopaedics approach to improve the outcome of delayed surgery for hip fracture in elderly patients with extensive comorbidities[8]. We believe that this is the first application of the Damage Control Orthopaedics in the setting of patient stratification for urgent hip surgery.

Not all orthopaedists accept Damage Control Orthopaedics. The arguments against this approach are that modern medicine advances allow

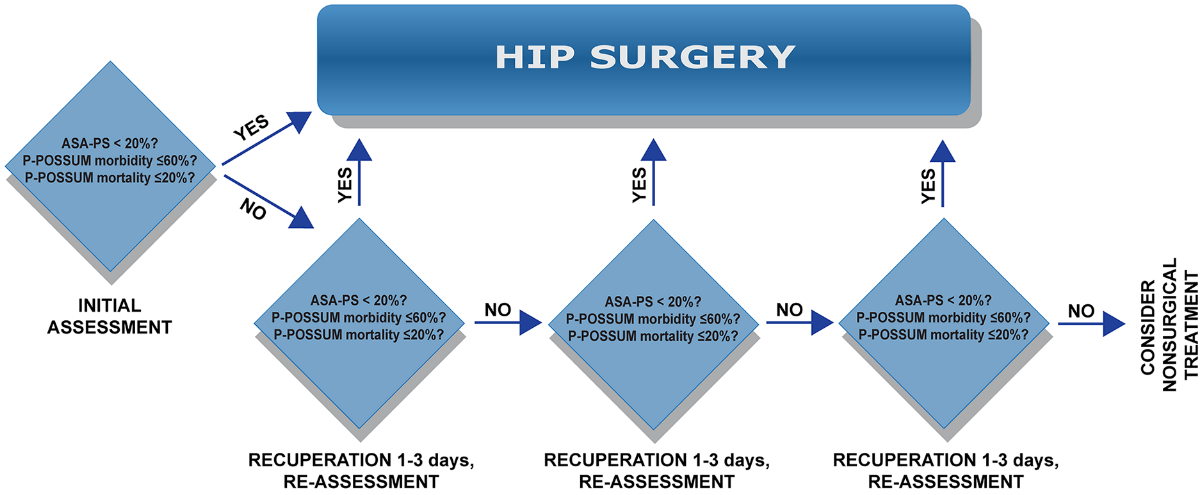

Figure 1. Proposed algorithm, based on Damage Control Orthopaedics approach, to stratify elderly comorbid patients for hip surgery. Patients are stratified based on ASA-PS and P-POSSUM scores. Those who are sufficiently fit will undergo early surgery within 48 hours. In other patients, nonsurgical measures will be applied for 1-3 days to stabilize the overall condition and to improve the comorbidity. This recuperation period is followed by repeated assessment. If necessary, recuperation is applied up to 2 times more. If after 3 recuperation periods the patient is found still not fit for surgery, nonsurgical treatment for hip fracture are considered.

or will soon allow to minimize the adverse consequences of the second, surgery-associated "hit"[71]. As well, hospital resources are drained more intensively if surgery is delayed. Also, even in polytrauma patients, application of Damage Control Orthopaedics not always yields clearly beneficial outcomes[72]; thereby, the usability of Damage Control Orthopaedics is still controversial. Therefore, newer concepts for trauma patients have begun to evolve, such as Early Appropriate Care[73].

Nonetheless, we believe that the Damage Control Approach is highly applicable to hip fractures in elderly patients with comorbidities. Unlike in polytrauma patients, the second "hit" in elderly comorbid patients arises substantially from the concomitant disease. Furthermore, even if the condition of primary injury permits early surgery, it is often the concomitant disease that prevents carrying out the surgery. This calls for nonsurgical measures to stabilize the overall patient condition and to address the concomitant disease. As concomitant diseases are frequent and pronounced in the elderly[65,74], it is not surprising that many of these patients cannot undergo the surgery for hip fracture within the recommended 48-hour time frame. In the next subsection, we will present an algorithm developed in our clinic on the basis of the Damage Control Orthopaedics to stratify patients and minimize the adverse consequence of surgery delay.

Damage Control Orthopaedics as the Approach to Minimize Adverse Consequences of surgery Delay in Elderly Comorbid Patients with hip Fracture

We have recently utilized this approach to address surgery delays in elderly patients with chronic renal failure who had sustained hip fractures[8].

Patient stratification for surgery was done as follows (Figure 1). We have examined patients' conditions and determined the surgery-associated risk using the ASA-PS and P-POSSUM scores. In the "Operative Parameters" part of the P-POSSUM score, we have entered "Major Operation" for operation type, "< 100 ml" for operative blood loss, and "No soiling" for peritoneal contamination. The estimates were based on our prior experience.

If the predicted patient risk was assessed as ASA-PS of < 20%, and P-POSSUM morbidity and mortality rates as, respectively, 60% and 20%, then such patient was considered as fit to undergo early surgery within 48 hours (Figure 1;[8]). If the patient condition was worse than the above criteria, the overall condition and comorbidity were addressed for 1-3 days, following which the ASA-PS and P-POSSUM assessment were repeated (Figure 1). If the patient met the above criteria, he or she underwent the surgery. If patient's condition was still too poor, a second recuperation period was initiated for 1-3 days, and subsequently, the assessments were repeated (Figure 1). If the decision was again to postpone the surgery, a third recuperation period was administered for 1-3 days (Figure 1). If the patient was still unfit for surgery, as demonstrated by ASA-PS and P-POSSUM scores, it was to be decided whether to continue with the surgery or switch to nonsurgical treatments instead (Figure 1;[8]).

As we demonstrate in our study, this approach has helped to minimize the negative consequences of surgery delay in these patients[8]. Specifically, postoperative adverse events were comparable between patients who had undergone early surgery and those who had been subjected to Damage Control Orthopaedics first, with the subsequent decision about carrying out the surgery.

Notably, we have used a standardized surgical approach (total hip arthroplasty and hemiarthroplasty) to minimize the variability associated with different types of surgery.

Conclusions

Surgery for hip fracture in the elderly comorbid patient still presents a challenge to orthopaedic surgeons. Here we discuss the application of Damage Control Orthopaedics to minimize negative sequelae of surgery delay beyond the recommended 48 hours. This delay arises from the necessity to improve the comorbidity before surgery. We have successfully applied the described algorithm in elderly patients with hip fracture and renal failure. Further investigations on this subject are urgently needed to establish international guidelines on approaches during patient recuperation prior to delayed surgery.

Conflicts of interest

The authors declare no conflicts of interest.

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