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The influence of orthopedic surgery on the incidence of post-operative delirium in geriatric patients: results of a prospective observational study

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ABSTRACT

Background: Postoperative delirium (PD) is a major concern in geriatric patients undergoing orthopedic surgery. This prospective observational study aims to examine the incidence of PD, to identify intervention-specific risk factors and to investigate the influence of orthopedic surgery on delirium.
Methods: From 2019 to 2020, 132 patients ≥70 years of age with endoprosthetic (Group E) or spinal surgery (Group S) were included. Upon admission, the ISAR score, the Nursing Delirium Screening Scale, potential risk factors, the ASA score, duration of surgery, type of anesthesia, blood loss, and hemoglobin drop were recorded. For risk factor analysis patients were grouped into Group D (delirium) and Group ND (no delirium). Primary endpoint was the occurrence of PD.
Results: Of 132 patients, 50 were included in Group E and 82 in Group S. Mean age and ISAR score were not significantly different between groups. Delirium rate in Group E and S was 12% vs. 18% ($p = 0.3$). Differences could be observed between Group D and ND in duration of surgery (173 min vs. 112 min, $p = 0.02$), postoperative hemoglobin drop (3.2 g/dl vs. 2.3 g/dl; $p = 0.026$), history of PD (23% vs. 11%, $p = 0.039$) and use of isoflurane (6 vs. 2). Type of surgery was not an independent risk factor ($p = 0.26$).
Conclusion: Specific type of orthopedic surgery is not an independent risk factor for PD. Prevention of PD should focus on duration of surgery and blood loss, particularly in patients with a history of PD. A possible delirogenic potential of isoflurane should be further studied.

1. Introduction

According to the ICD-10, delirium is an etiologically unspecified organic brain syndrome associated with a disorder of consciousness and having at least two disturbances of either attention, cognition, thought, memory, psychomotricity, emotionality and/or sleep-wake rhythm. Duration and severity are highly variable.

Hypoactive delirium is distinguished from hyperactive delirium, mixed forms are possible. Delirium is more frequent after surgery in the older adult and has significant negative patient-related and socioeconomic consequences: in addition to prolonged hospital stay,[1,2] cognitive deficits can persist for a longer time[3] and patients are more likely to be discharged from the hospital into nursing- and rehabilitation facilities.[4]

The incidence of postoperative delirium (PD) in older adults varies between 9% and 30% for general surgery,[5] 16%–44% for hip fractures[6] and 11%–55% for cardiac surgery.[7] The variability is explained by diagnostic difficulties, different screening tools and different study designs and inclusion criteria. Most postoperative delirium studies are retrospective, with the true incidence of PD likely to be higher than reported.[8] Common screening tools include the Nursing Delirium Screening Scale (Nu-DESC) and the (Confusion Assessment Method CAM) which have been described in a systematic review by van Velthuijse[9] to be the most adequate instruments to detect delirium. The Nu-DESC Score is a simple, well-validated, 5-item delirium detection tool[10] with a high sensitivity of

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94% and a specificity of 87%.[11] Leung et al.[12] found a very high interrater reliability ($\alpha = 0.096$). Unlike CAM, it does not require active cooperation by the patient.

Potential risk factors for PD have been reported in the past including: advanced age, comorbidities (stroke, CHD, diabetes mellitus, anemia, Parkinson's syndrome, depression, chronic pain and anxiety disorders), dehydration, hyponatremia and hypernatremia, anticholinergic medication, alcohol abuse, blood loss, duration of surgery and postoperative pain.[13] While most PD studies focus on a single surgical indication (e. g., arthroplasty, spine surgery, fracture treatment), comparative, prospective studies are rare. Whether the type of orthopedic intervention has an influence on the incidence of the PD is not conclusively clarified. Efficient preventive measures against PD require the preoperative identification of high-risk patients.

The purpose of this prospective observational study is to investigate the incidence of PD in a group of older adults with various orthopedic procedures and to investigate or identify risk factors. Included were patients with arthroplasty and spine surgeries.

2. Methods

Ethical approval for this study was provided by the Ethics Committee of our institution (N° 16–332).

From December 2019 to January 2021 all patients (at least 70 years old) who had either endoprosthetic (GROUP E; primary knee or hip total endoprosthesis) or spinal surgery in our tertiary referral hospital (GROUP S; decompression or spondylodesis) were included into this prospective observational cohort study after a signed consent was obtained. Exclusion criteria were age less than 70 years, existing preoperative delirium (measured by Nu-DESC Score), inability to consent (language barrier, existence of a legal guardian) preoperative lack of orientation to person, place and time during standard testing upon admission to the ward. This study was planned as a pilot study with a fixed duration of 1 year. Therefore, number of cases in our hospital during the study period determined the sample size. A sample size calculation was not possible, because there is no preexisting data on the effect of orthopedic surgery on PD. To minimize selection bias broad inclusion criteria were chosen.

Upon inclusion the ISAR Score (Identification of Seniors at Risk) was obtain during admission to the ward with a standardized sheet. The preoperative Nu-DESC scale and various potential risk factors and parameters (see Table 1) were evaluated by specially trained examiners. A blood sample was obtained from each participant one day prior to the operation and on each of the first three postoperative days for routine laboratory testing, which included the laboratory parameters stated in Table 1.

The primary endpoint was the occurrence of delirium within the first three postoperative days, which was detected by the daily application of the Nu-DESC scale on the surgical ward and/or post anesthesia care unit. The risk factors and parameters (Table 1) were queried again on each of the first 3 postoperative days. Other parameters additionally recorded or calculated during the first 3 postoperative days were: past history of delirium, American Society of Anesthesiologists (ASA) stage, preoperative oxygenation, duration of surgery, blood loss, drug used for general anesthesia, hemoglobin drop and blood transfusion. Patients were followed up for three days postoperative.

The collective of patients was divided into the Groups E and S (E: patients receiving endoprosthetic surgery; S: patients receiving spinal surgery), Groups D and ND (D: patients with postoperative delirium; ND: patients without PD), and Groups DS and DE (DS: patients receiving spinal surgery *with* PD; DE: patients receiving endoprosthetic surgery *with* PD). Due to the pilot nature of the study a matching between Groups E and S was not done. A statistical analysis of the characteristics and distribution of risk factors and parameters in each group was carried out. Differences between groups (E vs. S; D vs. ND; DE vs. DS) were evaluated for significance by univariate analysis using Chi-square test, *U* test and *t*-test. Significance level was set at 0.05. Additionally, a multivariate analysis using a logistic regression model with forward stepwise selection was performed for significant risk factors identified during univariate analysis to control for confounders. The statistical analysis was carried out using SPSS, version 24. This manuscript was drafted according to the STROBE Guidelines for observational studies.

3. Results

3.1. Study population

Of the 174 patients screened for eligibility, 133 patients met all inclusion criteria and were enrolled in the study. Of these, 132 were fully traceable during a postoperative period of at least three days and were included in the analysis. One patient could not be followed up because of prolonged intubation on an intensive care unit.

Table 1
Risk factors surveyed upon inclusion and on the first three postoperative days.

Risk factor	Items of evaluation
1. infection	☐ acute history of infection or confirmed presence of infection (eg, urinary tract infection, pneumonia, etc.)
2. hepatic impairment	☐ known liver dysfunction (eg cirrhosis), transaminase elevation, synthesis parameter decreased (quick, albumin, cholinesterase), cause excluded outside the liver (eg anticoagulation)
3. renal impairment	☐ at least grade III (GFR[a] <60 ml/min)
4. toxins (alcohol/drug use)	☐ Regular alcohol and/or drug use currently or in the past
5. electrolyte imbalance	☐ hyper-/hypokalemia, hyper-/hyponatremia, hyper-/hypocalcemia
6. neurological disease: e.g. Stroke, intracranial hemorrhage, Parkinson's	☐ at least one described event is acute or in the past
7. hypoxia	☐ O_2 saturation <90%, cyanosis
8. anemia	☐ hemoglobin value below age and sex specific norm
9. endocrine disorder such as diabetes mellitus or thyroid disease	☐ blood sugar> 200 mg/dl and/or positive medical history ☐ TSH[b] increased or decreased and/or positive history
10. shock	☐ positive shock index
11. delirogenic drugs	☐ anticholinergic drugs ☐ barbiturates ☐ Parkinson's medication ☐ neuroleptics

[a] GFR: glomerular filtration rate.
[b] TSH: Thyroid stimulating hormone.

Of the 132 patients, 71 were male and 61 female. The average age was 77.1 years (range: 70–90, SD ± 4.3). 82 patients underwent spinal surgery, 50 patients underwent arthroplasty. The median ISAR Score was 2. 17 of the 132 patients (13%) had a history of previous PD. Details on the procedures can be found in Table 2.

3.2. Group E vs. Group S

The characteristics of Group E and S are shown in Table 3. Regarding duration of surgery and difference in hemoglobin preoperatively/postoperatively, statistically significant differences were found. Regarding the potential risk factors shown in Table 1 incidences of renal impairment (74% vs 32%; p = 0.03), neurological disease (18% vs 2%; p = 0.005), and electrolyte disorder (39% vs. 22%; p = 0.043) were statistically significant different between Groups S and E. The median sum of risk factors was statistically significant different between Groups S and E (2 vs. 1; p = 0.005).

Of the 132 patients enrolled, 22 (16.7%) had PD within the first three postoperative days. In 18 of the 22 (81%) PD patients, delirium occurred on the first postoperative day, with the remaining four (19%) occurring on the second postoperative day. On the third postoperative day, no new PD was detected in any of the 132 patients. In Group S, delirium occurred in 16 of 82 patients (20%), in Group E postoperative delirium was found in 6 of 50 patients (12%). The difference was not statistically significant (p = 0.26).

3.3. Group D vs. Group ND

The following characteristics of the groups D and ND were found (Table 4):

Duration of surgery (173min vs 112min; p < 0.001), blood loss (826 ml vs. 544 ml; p = 0.04), postoperative hemoglobin (9.4 g/dl vs. 10.6 g/dl; p = 0.01), the difference between pre- and postoperative hemoglobin (3.2 g/dl vs. 2.3 g/dl; p = 0.005), preoperative oxygenation (94.8% vs. 96.6%; p = 0.02) and history of PD (23% vs 11%, p = 0.04) were statistically significantly different between Group D and ND. Use of delirogenic medication was statistically significantly higher in Group D compared to Group ND (32% vs 13%; p = 0.037). The type of intervention did not differ statistically significantly between the two groups (p = 0.26). Regarding other potential risk factors, the distribution of these did not differ statistically significantly between Group D and ND. Of the three patients with a propofol-free anesthesia two were in Group D and one was in Group ND (p = 0.019). Of the ten patients with an isoflurane anesthesia six were in Group D and four were in Group ND (p=<0.001).

In the multivariate analysis duration of surgery (p = 0.02), difference between pre- and postoperative hemoglobin (p = 0.03), history of PD (p = 0.04) and use of isoflurane (p < 0.001) were significant risk factors. Odds ratios are displayed in Fig. 1. Type of surgery was not significant (p = 0.81) with an odds ratio of 1.3 (95% CI 0.3 to 5.4).

Table 2
Characteristics of the study population.

Number of spine operations	82
indications:	
- degeneration	67
- fracture	15
procedure:	
- spondylodesis	46
- decompression	36
number of endoprosthetic operations	50
indications:	
- primary bicondylar knee replacement	19
- primary total hip replacement	31

Table 3
Parameters and differences of Group S (spine patients, n = 82) and Group E (endoprosthetic patients, n = 50).

	Group S	Group E	p-value*
mean age (a)	76.9	77.6	0.25
median ISAR [a] Score	2	1	0.19
median ASA [b] Score	3	3	0.9
BMI [c] (kg/m^2)	29.1	28.9	0.49
median number of risk factors	2	1	**0.01**
mean duration of operation (min)	143	88	**<0.001**
mean bloodloss (ml)	560	652	0.41
hemoglobin preoperative (g/dl)	12.7	13	0.31
hemoglobin postoperative (g/dl)	10.5	10.2	0.53
difference hemoglobin pre/postop. (g/dl)	2.2	2.7	**0.03**
patients with blood transfusion (%)	5 (6%)	4 (8%)	0.69
patients with history of PD [d] (%)	11 (13%)	6 (12%)	0.64
preoperative oxygen saturation (%)	96.1	96.7	0.32
patients with delirogenic medication	17 (20%)	5 (10%)	0.11
patients with infection	14 (17%)	6 (12%)	0.43
patients with hepatic impairment	1 (1.2%)	3 (6%)	0.12
patients with renal impairment	42 (51%)	16 (32%)	**0.03**
patients with neurological disease	15 (18%)	1 (2%)	**0.01**
patients with alcohol/drug abuse	16 (20%)	6 (12%)	0.26
patients with electrolyte disorder	32 (39%)	11 (22%)	0.32
patients with endocrine disorder	41 (50%)	27 (54%)	0.66
patients with non-propofol anesthesia	0 (0%)	3 (6%)	**0.03**
patients with isoflurane anesthesia	6 (7%)	4 (8%)	0.61

Notes: * p-values <0.05 printed in bold.
[a] ISAR: Identification of Seniors At Risk.
[b] ASA: American Society of Anesthesiologists.
[c] BMI: Body Mass Index.
[d] PD: postoperative delirium.

Table 4
Parameters and differences of Groups D (delirium, n = 22) and ND (no delirium, n = 110).

	Group D	Group ND	p-value*
mean age (a)	77.6	77.1	0.61
median ISAR[a] Score	2	2	0.24
median ASA[b] Score	3	3	0.22
mean BMI[c] (kg/m^2)	29.1	29.1	0.96
median number of risk factors	3	2	0.63
mean duration of operation (min)	173	112	**<0.001**
mean bloodloss (ml)	826	544	**0.04**
hemoglobin preoperative (g/dl)	12.6	12.8	0.55
hemoglobin postoperative (g/dl)	9.4	10.6	**0.01**
difference hemoglobin pre/postop. (g/dl)	3.2	2.3	**0.01**
patients with blood transfusion	2 (9%)	7 (6%)	0.60
patients with history of PD[d]	5 (23%)	12 (11%)	**0.04**
preoperative oxygen saturation (%)	94.8	96.6	**0.02**
patients with delirogenic medication	7 (32%)	15 (13%)	**0.04**
patients with infection	5 (22%)	15 (13%)	0.28
patients with hepatic impairment	1 (4.5%)	3 (2.7%)	0.65
patients with renal impairment	10 (45%)	48 (43%)	0.88
patients with neurological disease	5 (22%)	11 (10%)	0.09
patients with alcohol/drug abuse	5 (22%)	17 (15%)	0.4
patients with electrolyte disorder	10 (45%)	33 (30%)	0.16
patients with endocrine disorder	12 (55%)	56 (51%)	0.76
patients with non-propofol anesthesia	2 (9%)	1 (0.1%)	**0.02**
patients with isoflurane anesthesia	6 (27%)	2 (0.2%)	**<0.001**

Notes: * p-values <0.05 printed in bold.
[a] ISAR: Identification of Seniors At Risk.
[b] ASA: American Society of Anesthesiologists.
[c] BMI: Body Mass Index.
[d] PD: postoperative delirium.

3.4. Delirium patients (Group DE and Group DS)

Looking at only the 22 patients with PD, Group DS and DE

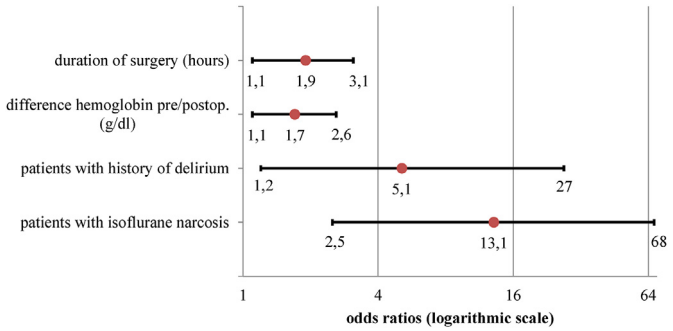

Fig. 1. Odds ratios for developing a postoperative delirium for significant risk factors in multivariate analysis. Number below • indicates the odds ratio, numbers to the left and right indicate the 95% confidence intervall

differed significantly only in terms of mean duration of surgery (212 min vs. 70 min, p = 0.0005), but not blood loss, postoperative hemoglobin and difference in pre/postoperative hemoglobin. Distribution of potential risk factors (stated in Table 1) did not differ significantly between Group DE and DS. Two patients in Group DE had a non-propofol anesthesia, whereas no patient in Group DS had a non-propofol anesthesia (p = 0.02).

4. Discussion

The postoperative delirium of the older adult is a common complication after surgical procedures. This prospective observational study on the incidence of PD in 132 patients (at least 70 years old) receiving orthopedic surgery could not identify the type of surgical procedure as an independent risk factor, but identified operation time, postoperative hemoglobin drop and history of PD as significant risk factors.

There are only a few prospective studies investigating the incidence of PD in older adults: Brown et al.[14] in a prospective study of 89 patients over 70 years of age with lumbar and cervical spine surgery found a PD incidence of 40.5%. Seo et al.[15] report an incidence of 24.3% in spine patients older than 60 years in their prospective study (n = 70). In the field of arthroplasty a 10% postoperative delirium rate was found by Jankowski et al.[16] in a prospective study involving 418 patients of at least 65 years of age. Chen et al.[17] found an incidence of 16.5% in a prospective study with 221 total joint arthroplasty patients (>60 years). For the first time, this study tried to prospectively examine whether the type of intervention is a risk factor for the development of the PD in an orthopedic, geriatric patient collective. There is no fixed definition of what constitutes a “geriatric patient”. While the formal age-threshold is often considered to be 65 years, there is a wide inter-individual variety at what age a patient requires treatment by a geriatrician. Live expectancy is rising and age is only one factor to be considered when defining a “geriatric patient”.[18] Therefore, we included only patients ≥70 years old. The overall median ISAR Score in our study population was 2. In this study it was not a predictor for the development of PD with the median score being 2 in both patients with and without PD.

In our study of 132 patients with a minimum age of 70 who had either spinal surgery or endoprosthetic surgery, the total PD rate was 16.7%. The average number of potential delirium risk factors (2 vs. 1, p = 0.005), the average duration of surgery (88 min vs. 143 min; p = 0.0001), the average postoperative hemoglobin drop (2.2 g/dL vs. 2,7 g/dL; p = 0.03), incidence of renal impairment (51% vs. 32%; p = 0.03) and neurological disease (18% vs. 0.02%; p = 0.005) were significantly different between Groups E and S, and these differences may act as confounders. Despite the differences, the incidence of PD was not significantly different between the two Groups E and S: it was 20% in the spine group and 12% in the endoprosthetics group (p = 0.26). The above-mentioned studies show a large range of PD incidence and this is probably due to different study designs (e. g. minimum age of patients included; use of different tools for detecting PD). Although this makes it difficult to compare study results, the PD incidence of our collective confirms the range described in prospective studies.[14–17] The comparatively low overall PD incidence of 16.7% may be due to differences in study population of studies with considerably higher incidences like Brown[14] and Seo.[15] The type of PD detection tool used may also play a role: although the Nu-Desc has a good validity and reliability no data on internal consistency have been published so far.[9] Furthermore, it requires no active participation and is only observational. Hypoactive delirium may thus be underestimated.

When PD and no-PD patients were compared, the type of intervention was not an independent risk factor for delirium (p = 0.27), whereas the duration of surgery differed significantly between PD and non-PD patients (173min vs. 112min. p = 0.0002). The duration of surgery thus played a decisive role in this study as a risk factor for developing PD. The interpretation of the duration of surgery as a risk factor varies. It is stated by the European Society of Anesthesiology as a risk factor on the basis of 3 prospective studies[13,19–21] of which only one[19] included orthopedic surgery. This is also confirmed in a meta-analysis by Shi et al.[22] of six studies focusing on spine surgery. In contrast a prospective study by Chen et al.[17] with 212 arthroplasty patients found that operating time was not a risk factor for PD. In a retrospective study by Wang[23] with 306 patients undergoing hip joint replacement surgery, the mean duration of surgery was not increased in patients with PD.

In addition to the duration of surgery, the present study identified intraoperative blood loss, a low postoperative hemoglobin level and a high difference between pre- and postoperative hemoglobin level as a risk factor in the univariate analysis. A meta-analysis by Yang[24] also found low postoperative hemoglobin levels as a risk factor. There is probably a high internal, pathophysiological relationship between three of these factors: absolute postoperative hemoglobin level and differences between pre- and postoperative hemoglobin levels are directly and causally correlated with intraoperative blood loss. Accordingly, in the multivariate analysis only the difference between pre- and postoperative hemoglobin levels was statistically different, probably due to covariance. While delirium patients had an average postoperative hemoglobin value of less than 10 g/dL, it averaged just above 10 g/dL in non-delirium patients. According to the guidelines of the American Association of Blood Banks (AABB)[25] a red blood cell transfusion threshold of 8 g/dL is recommended for patients undergoing orthopedic surgery. This recommendation is based on the review of 31 RCTs comparing a restrictive red blood cell transfusion threshold of 7–8 g/dL to a liberal threshold of 9–10 g/dL, the former not being associated with higher rates of adverse clinical outcomes. However, the adverse outcomes evaluated in these RTCs did not include PD. Furthermore, there is a lack of prospective intervention studies that investigate the benefit of red blood cell transfusions for PD prevention: to our knowledge there are only two prospective studies investigating the benefits of a liberal transfusion threshold to reduce PD occurrence, with inconsistent findings. Fan et al.[26] found a lower rate of PD in patients receiving red blood cells at a hemoglobin level ≥11.3 g/dL compared to a threshold of ≥9.7 g/dL. In contrast, Blandfort et al.[27] found no differences in PD incidence between patients with a target hemoglobin level of ≥10 g/dL compared to patients with a target hemoglobin level of ≥8 g/dL. Accordingly, it is still unclear whether a red blood cell transfusion threshold of >8 or 10 g/dL can lower the rate of PD or if patients under risk for PD should have a target level for postoperative

hemoglobin of ≥10 or ≥8 g/dL. Intraoperative management of bleeding may decrease the incidence of PD, according to the findings of the present study.

The definition of PD according to the ICD or DSM does not say anything about how long after surgery the occurrence of delirium can be considered "postoperative".[28,29] Accordingly, study designs on PD vary: some studies screened for PD in the first two postoperative days, others within the first four or five days.[14,16,19,30,31] We choose to screen for PD within the first three postoperative days based on the findings of Robinson et al., who found the average time until onset of PD to be 2.0 ± 0.9 days. In the present study, delirium occurred mostly on the first (81% of cases) and second postoperative day (19% of cases). No new delirium was detected on the third postoperative day. In the prospective study by Brown et al.,[14] in which only spine patients were studied, delirium occurred in 44% of cases on the first day and in 42% of cases on the second day (with a total delirium rate of 40%). This discrepancy may be due to methodological differences: Brown et al. used the CAM and CAM-ICU tool for delirium diagnostics, whereas in our study the Nu-DESC Scale was used. The Nu-DESC Score is a simple, well-validated, 5-item delirium detection tool.[10] It does not require active cooperation by the patient. Each item has a severity of 0 (symptom not present), 1 (symptom present, mild) or 2 (symptom present and more pronounced). A total score of 2 of higher indicates a delirium. According to a study by Radtke et al.[11] comparing different delirium detection tools the Nu-DESC has a significantly higher sensitivity of 94% compared to the CAM-tool with only 43% sensitivity.

Previous PD is consistently found in studies to be a risk factor for developing PD again[24,32] and this was confirmed in our study: in our collective, patients with a history of PD were five times as likely to develop PD again (23% vs 11%, p = 0.039; OR: 5.1 [1.1.-23.7]).

Use of anesthetics showed several differences between PD and non-PD patients. While the different distribution of isoflurane anesthesia was statistically significant between patients with and without PD in the multivariate analysis (6 vs. 2; p = 0.002; OR: 19.2 [2.9−126), further interpretation of the statistical significance and anesthetic regimens (e. g. isoflurane versus no-isoflurane) based on this finding is very limited due to the low number of cases (n = 10) and due to the non-randomized use of isoflurane. Clinical data on the delirogenic potential of isoflurane is rare. Only three prospective studies with relatively small sample sizes investigated this issue, all of which showed higher rates of postoperative cognitive dysfunction in patients receiving a isoflurane anesthesia compared to propofol.[33–35] However, these studies do not investigate specifically the entity of delirium. The effects of other intravenous or inhalative anesthetics like thiopentale or levoflurane were not further analyzed in our study since numbers were very low (n = 1 and n = 2).

The ASA Classification System cannot serve to predict operative risk, yet it is closely related to postoperative outcomes in numerous fields of surgery.[36] In our study the median ASA physical status in both PD and non-PD patients was 3 (indicating severe systemic disease), with no statistically significant difference (p = 0.22). Findings on ASA Classification as a predictor for PD are inconsistent in prospective studies. Brown et al.[14] found a statistically significant higher ASA status in PD patients receiving spine surgery compared to non PD patients. A meta-analysis by Smith et al. on the outcomes for total hip replacement after hip fracture showed a higher probability for PD in ASA 3 and 4 patients compared to ASA 1 and 2 patients.[37] In contrast, Contin et al.[38] found no difference between ASA 1 and 2 and ASA 3 and 4 patients in a prospective study of patients receiving elective orthopedic surgery.

There are several limitations to our study. Although the number of patients included is larger than in most aforementioned prospective studies, it may still be too small a sample size to draw general conclusions from it. This is especially true for the findings concerning the role of isoflurane as a potentially delirogenic anesthetic (n = 10). Since this is a monocentric study in a tertiary referral center the study population may not be representative for geriatric patients in general and results of our study should be generalised with caution (selection bias). Groups E and S were not matched and differed in the distribution of potential PD risk factors as stated above. This limits comparability and conclusions in regards to the role of type of orthopedic surgery for PD development.

5. Conclusion

Specific type of orthopedic surgery may not be an independent risk factor for PD, but prospective studies with matched intervention groups and a longer follow-up are needed to prove the feasibility of this finding. Prevention of PD should focus on duration of surgery and blood loss, particularly in patients with a history of PD. A possible delirogenic potential of isoflurane should be further studied.

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Authors' contributions

MJS and KS conceived the study, were involved in conception and planning of the study design and supervised the collection of the data. KS performed the statistical analysis. TA supported data collection. The collected data and results were discussed and interpreted with KS, MJS, JB, PE, AY and TA. All authors wrote and revised the manuscript. All authors have read and approved of the final submitted manuscript.

Ethical approval

Ethical approval for this study was provided by the Ethics Committee of our institution (N° 16−332).

Declaration of competing interest

The authors have no conflicts of interest to declare that are relevant to the content of this article. Independent from the presented study, T. A received research grants from CytoSorbents, Corpuls, Medtronic, German Federal Ministry of Economics and Energy (Central innovation program for medium-sized companies, ZIM Program), and the Center of Integrated Oncology (CIO) Cologne-Bonn.

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