Predictors of delirium after cardiac surgery in patients with sleep disordered breathing

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This prospective observational study shows that, among established risk factors, central sleep apnoea is independently associated with post-operative delirium in patients undergoing elective cardiac surgery
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ABSTRACT
Introduction: Delirium ranks among the most common complications after cardiac surgery. Although various risk factors have been identified, the association between sleep disordered breathing (SDB) and delirium has barely been examined so far. Here, our objectives were to determine the incidence of post-operative delirium and to identify the risk factors for delirium in patients with and without SDB.
Methods: This subanalysis of the ongoing prospective observational study CONSIDER-AF (ClinicalTrials.gov identifier NCT02877745) examined risk factors for delirium in 141 patients undergoing cardiac surgery. The presence and type of SDB were assessed with a portable SDB monitor the night before surgery. Delirium was prospectively assessed with the validated Confusion Assessment Method for the Intensive Care Unit on the day of extubation and for a maximum of 3 days.
Results: Delirium was diagnosed in 23% of patients: in 16% of patients without SDB, in 13% with obstructive sleep apnoea and in 49% with central sleep apnoea. Multivariable logistic regression analysis showed that delirium was independently associated with age ⩾70 years (OR 5.63, 95% CI 1.79–17.68; p=0.003), central sleep apnoea (OR 4.99, 95% CI 1.41–17.69; p=0.013) and heart failure (OR 3.3, 95% CI 1.06–10.35; p=0.039). Length of hospital stay and time spent in the intensive care unit/intermediate care setting were significantly longer for patients with delirium.
Conclusions: Among the established risk factors for delirium, central sleep apnoea was independently associated with delirium. Our findings contribute to identifying patients at high risk of developing post-operative delirium who may benefit from intensified delirium prevention strategies.

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Introduction

Post-operative delirium ranks among the most common complications after cardiac surgery [1]. The incidence of delirium after cardiac surgery ranges between 30% and 50% [2]. Post-operative delirium is characterised as an acute state of confusion and inattention that may be accompanied by an altered level of consciousness and disorganised thinking [3]. Until recently, delirium was assumed to be a transient mental disorder with few consequences and self-limiting characteristics. However, post-operative delirium has been linked to increased morbidity and mortality [4], prolonged length of hospital stay [5], cognitive and functional decline [6] as well as reduced quality of life [7].

The prevention of post-operative delirium and its harmful sequelae requires knowledge of the risk factors involved. Numerous studies have shown that post-operative delirium is associated with age, diabetes mellitus, atrial fibrillation, history of stroke, depression, alcohol abuse, acute kidney injury, hypoalbuminaemia and anaemia [1, 6, 8, 9]. Although various risk factors for delirium have been identified, the association between sleep disordered breathing (SDB) and delirium has barely been examined so far.

SDB is a common disorder affecting approximately 13% of males and 6% of females aged between 30 and 70 years [10]. Epidemiological studies have shown a high prevalence of SDB in patients with coronary artery disease due to shared risk factors and most likely a bidirectional causal relationship [11]. About 46% of patients with chronic heart failure have SDB, of whom approximately 50% are diagnosed with central sleep apnoea (CSA) and 50% with obstructive sleep apnoea (OSA) [12, 13].

To date, few prospective observational studies have addressed the association between SDB and post-operative delirium [14, 15], of which one focused on post-operative delirium in patients undergoing cardiac surgery [15]. Previous studies are limited by relatively small study populations and the fact that CSA was not taken into account.

The objectives of the present subanalysis were to determine the incidence of post-operative delirium and to identify predisposing risk factors for post-operative delirium in patients with and without SDB who undergo elective coronary artery bypass grafting (CABG) surgery.

Methods

Study design and patients

This subanalysis is part of the ongoing prospective observational study CONSIDER-AF (Impact of SDB on atrial fibrillation and peri-operative complications in patients undergoing CABG surgery; ClinicalTrials.gov identifier NCT02877745) that evaluates the impact of SDB on the rate of major adverse cardiac and cerebrovascular events in patients undergoing elective CABG surgery at the Dept of Cardiothoracic Surgery of the University Medical Center Regensburg (Regensburg, Germany) [16]. This study was approved by the Ethics Committee of the University of Regensburg (approval 15-101-0238).

Between May 2016 and October 2017, patients aged between 18 and 85 years were tested for eligibility. Informed consent was obtained from all eligible patients who were willing to participate in the study. Exclusion criteria were severe obstructive pulmonary disease, oxygen therapy, nocturnal positive airway pressure support or mechanical ventilation and need of vasopressors, inotropes or circulatory assist devices [16]. To reduce bias, SDB monitoring and peri-operative clinical treatment were performed in a standardised manner (*e.g.* “fast-track recovery” care protocol [16]; see supplementary material). Medical staff, including nurses, anaesthesiologists and intensive care unit (ICU) physicians, as well as physiotherapists, were blinded to the patients’ diagnosis of SDB. Thus, none of the patients received specific treatment for SDB in the peri-operative phase. For assessing post-operative outcome, length of hospital stay and time spent in the ICU/intermediate care (IMC) settings were assessed. Length of hospital stay was defined as the time between surgery and the day of discharge [17].

Assessment of post-operative delirium

Delirium was repeatedly assessed by trained medical staff using the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) on the day of extubation and for a maximum of 3 days, except weekends and holidays [18]. The validated CAM-ICU is recommended by the American College of Critical Care Medicine [19]. Before CAM-ICU assessment, the sedative state was evaluated as a standard feature using the Richmond Agitation–Sedation Scale (RASS) [20]. See the RASS and CAM-ICU worksheets in supplementary figure E1 for more details.

Statistical analysis

Data management and statistical analysis of this subanalysis were conducted according to the data handling plan described in the published study protocol of the CONSIDER-AF study [16]. Statistical analyses were done with SPSS version 24.0 (IBM, Armonk, NY, USA). Data are presented as mean with standard deviation for normally distributed data and as median (interquartile range (IQR)) for nonnormally distributed data; categorical variables are described as absolute and relative frequencies. Differences between groups were compared using the t-test for normally distributed continuous variables, the Wilcoxon–Mann–Whitney test for nonnormally distributed continuous variables and the Chi-squared test of independence for categorical variables. Univariable logistic regression analyses were conducted with predisposing risk factors as independent variables and with delirium as a dependent variable. A multivariable logistic regression model, including all independent variables with $p<0.1$ in the univariable models, was calculated. A two-sided p-value $\leqslant 0.05$ was considered statistically significant for all analyses.

Results

Study patients

In total, 241 patients were recruited for the ongoing prospective observational CONSIDER-AF study. 62 patients were excluded from this subanalysis due to insufficient SDB monitoring and withdrawal of consent (figure 1). As no prospective study-specific assessment of post-operative delirium had been conducted on weekends and holidays, 38 patients were omitted from the present subanalysis of CONSIDER-AF. The demographics of patients who were excluded from the subanalysis population were similar to the subanalysis cohort (supplementary table E1).

Thus, the final subanalysis cohort consisted of 141 patients who were classified according to the presence of post-operative delirium (figure 1). The mean±SD age of the analysis population was 68±9 years and 87% were male. The median apnoea–hypopnoea index (AHI) was 15.8 events·h^{-1}. Among the patients of the subanalysis population, 51% had previously undiagnosed SDB, 26% OSA and 25% CSA. For prevalence rates of cardiovascular risk factors, other comorbidities and laboratory data, refer to table 1. For nocturnal respiration data, refer to table 2. Baseline data and nocturnal respiration data are shown according to the presence of post-operative delirium in supplementary tables E2 and E3, respectively.

Incidence of post-operative delirium

Post-operative delirium according to CAM-ICU criteria was diagnosed in 23% of patients (supplementary table E2). Post-operative delirium was significantly more frequent in patients with CSA than in patients

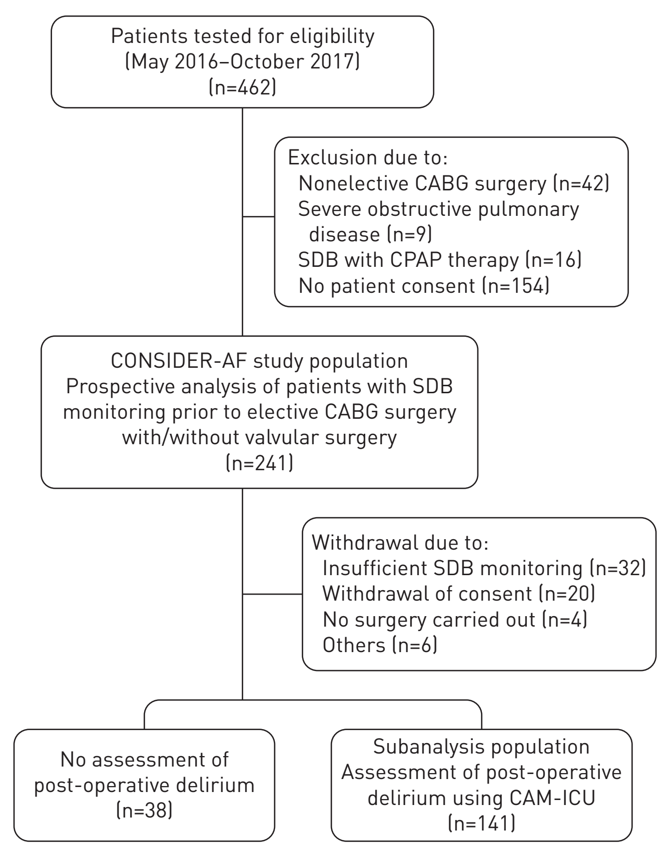

FIGURE 1 Study flowchart. CABG: coronary artery bypass grafting; SDB: sleep disordered breathing; CPAP: continuous positive airway pressure; CAM-ICU: Confusion Assessment Method for the Intensive Care Unit.

TABLE 1 Patient characteristics: baseline variables of the study population

Subjects	141
Age years	68±9
Male	123 (87)
BMI kg·m^{-2}	28.7±4.0
Cardiovascular risk factors	
Hypertension	119 (84)
Hyperlipoproteinaemia	91 (64)
Diabetes mellitus	45 (32)
Smoking	88 (62)
Family history of CAD	50 (36)
Comorbidities	
Heart failure (NT-proBNP cut-off)[#,¶]	41 (31)
NYHA class III/IV	44 (31)
LV ejection fraction %	58.1±9.9
LV ejection fraction <55%	29 (21)
Atrial fibrillation	31 (22)
History of TIA or stroke	20 (14)
Respiratory disease	9 (6)
Depression	6 (4)
History of alcohol abuse[+]	17 (13)
Laboratory data	
NT-proBNP[#] pg·mL^{-1}	408 (112–1166)
Haemoglobin g·dL^{-1}	14.2 (12.7–15.2)
Creatinine mg·dL^{-1}	1.0 (0.9–1.2)
GFR mL·min^{-1}·1.73 m^{-2}	75 (57–89)
Sodium mmol·L^{-1}	140 (139–142)
Albumin g·L^{-1}[§]	37.8 (36.4–40.0)

Data are presented as n, n (%), mean±SD or median (interquartile range). BMI: body mass index; CAD: coronary artery disease; NT-proBNP: N-terminal pro-brain natriuretic peptide; NYHA: New York Heart Association; LV: left ventricular; TIA: transient ischaemic attack; GFR: glomerular filtration rate. #: n=131; ¶: NT-proBNP ⩾450 pg·mL^{-1} (patients <50 years of age), ⩾900 pg·mL^{-1} (patients 50– <75 years of age) or ⩾1800 pg·mL^{-1} (patients ⩾75 years of age); +: >10 g alcohol per day (females) or >20 g alcohol per day (males); §: n=48.

with OSA or without SDB (49% *versus* 14% and 16%, respectively; p<0.001) (figure 2). Post-operative delirium most commonly occurred on post-operative day 1 and 2.

Predisposing risk factors for post-operative delirium

The prevalence rates of potential risk factors for post-operative delirium are shown in figures 2 and 3. The median AHI was significantly higher in patients with post-operative delirium than in those without delirium (23.7 *versus* 14.4 events·h^{-1}; p=0.028) (supplementary table E3). Prevalence rates of OSA were similar in both patient groups. Patients with post-operative delirium had CSA significantly more often

TABLE 2 Nocturnal respiration data of the study population

Total recording time min	483 (465–500)
Apnoea–hypopnoea index events·h^{-1}	15.8 (9.6–29.2)
Obstructive apnoea index events·h^{-1}	4.2 (1.9–8.9)
Central apnoea index events·h^{-1}	2.0 (0.5–8.5)
Oxygen desaturation index events·h^{-1}	13.6 (6.6–27.0)
Mean S_{pO_2} %	92 (91–93)
Minimum S_{pO_2} %	82 (77–85)
Time S_{pO_2} <90%/total recording time %	9.4 (1.9–22.4)
Sleep disordered breathing	72 (51)
Obstructive sleep apnoea	37 (26)
Central sleep apnoea	35 (25)

Data are presented as median (interquartile range) or n (%). S_{pO_2}: arterial oxygen saturation measured by pulse oximetry.

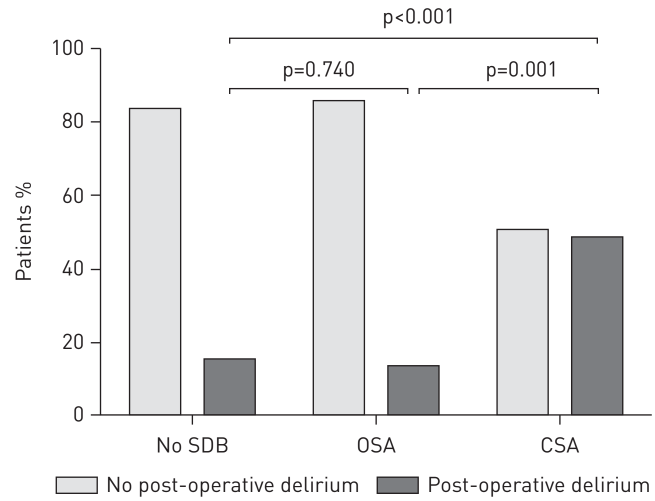

FIGURE 2 Central sleep apnoea (CSA) as predictor of the incidence of post-operative delirium. SDB: sleep disordered breathing; OSA: obstructive sleep apnoea. Comparison of the incidence of post-operative delirium with or without the presence of SDB.

than patients without delirium (51% *versus* 17%; p<0.001) (supplementary table E3). We found no significant association of reduced mean arterial oxygen saturation measured by pulse oximetry (S_{pO_2}) and prolonged time S_{pO_2} <90%/total recording time with post-operative delirium (supplementary figure E3).

Older patients (age ⩾70 years) experienced post-operative delirium significantly more often than younger patients (41% *versus* 10%) (figure 3a). A history of transient ischaemic attack or stroke increased the incidence of post-operative delirium from 18% to 55% (figure 3b). Post-operative delirium occurred in 16% of patients without heart failure, but in 44% of patients with heart failure (figure 3c), and in 16% of patients without anaemia, but in 47% of patients with anaemia (figure 3d). While the duration of bypass was significantly longer in patients with post-operative delirium compared with patients without post-operative delirium, we found no significant difference in the type of surgery and further surgery details or in the peri-operative administration of anaesthetics between patients with and without post-operative delirium (supplementary table E5)

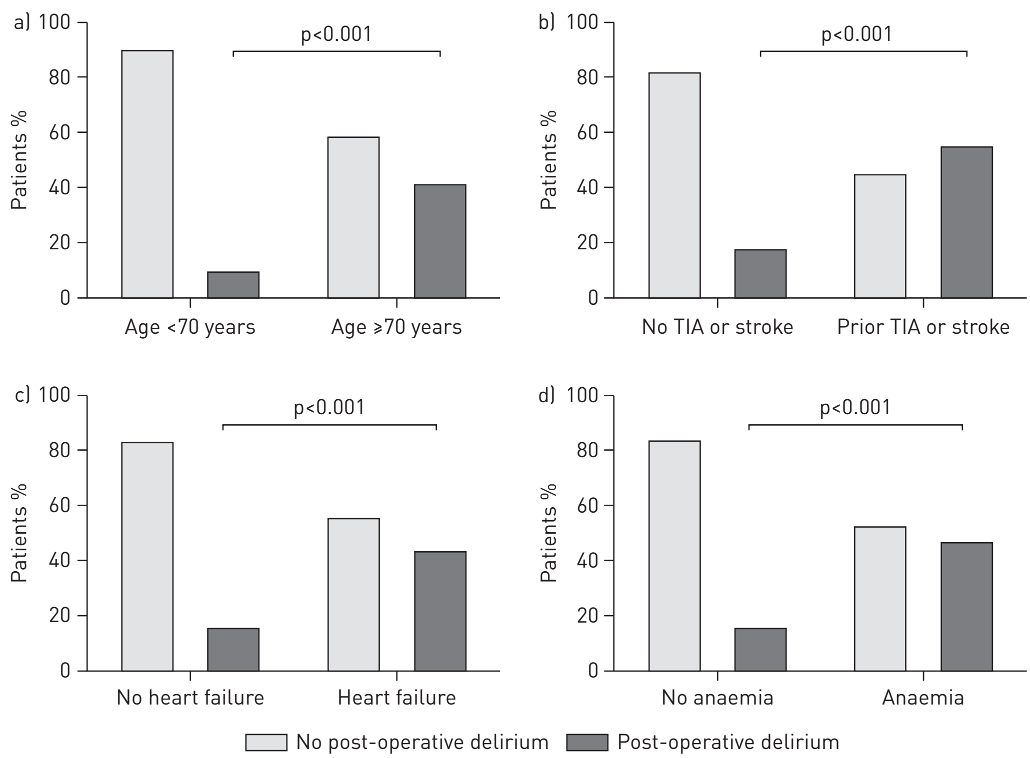

FIGURE 3 Pre-operative predictors of the incidence of post-operative delirium. TIA: transient ischaemic attack. Comparison of the incidence of post-operative delirium with or without the presence of independent pre-operative predictors: a) age, b) history of TIA or stroke, c) heart failure and d) anaemia.

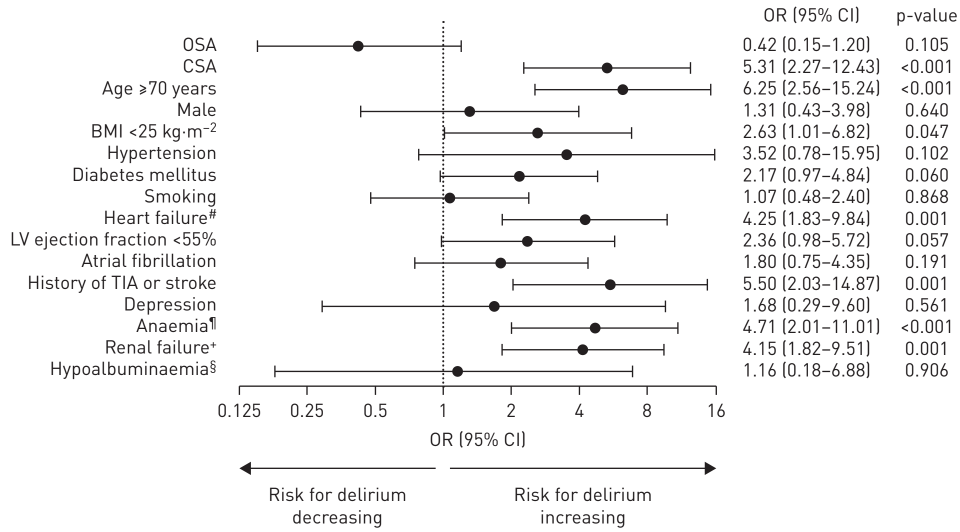

FIGURE 4 Pre-operative predictors of post-operative delirium: forest plot of pre-operative risk factors for post-operative delirium. OSA: obstructive sleep apnoea; CSA: central sleep apnoea; SDB: sleep disordered breathing; BMI: body mass index; LV: left ventricular; TIA: transient ischaemic attack. #: N-terminal pro-brain natriuretic peptide ⩾450 pg·mL^{-1} (patients <50 years of age), ⩾900 pg·mL^{-1} (patients 50–<75 years of age) or ⩾1800 pg·mL^{-1} (patients ⩾75 years of age); ¶: haemoglobin <12 g·dL^{-1} (females) or <13 g·dL^{-1} (males); +: glomerular filtration rate <60 mL·min^{-1}·1.73 m^{-2}; §: albumin ⩽35 g·L^{-1} (n=48).

Among pre-operative factors, age ⩾70 years, history of transient ischaemic attack or stroke, CSA, anaemia, heart failure, renal failure and body mass index were significantly associated with post-operative delirium (figure 4). Multivariable logistic regression analysis showed that post-operative delirium was independently associated with age ⩾70 years, CSA and heart failure (table 3). We replaced the independent variable "heart failure" with "left ventricular ejection fraction <55%" in an alternative multivariable model, which yielded similar results (CSA: OR 6.477, 95% CI 1.977–21.219; p=0.002; left ventricular ejection fraction <55%: OR 2.115, 95% CI 0.693–6.455; p=0.188). The independent association between CSA and post-operative delirium also remained significant in an extended multivariable model that additionally accounted for type of surgery and pre-operative need for loop diuretics (CSA: OR 4.33, 95% CI 1.17–16.11; p=0.029) (supplementary table E6).

Assessment of post-operative treatment and length of hospital stay

While in the early post-operative phase oxygen flow rates among patients with and without SDB were similar, oxygen flow rates were significantly higher in patients with SDB compared with patients without

TABLE 3 Multivariable logistic regression analysis for post-operative delirium as a dependent variable: association of pre-operative parameters with post-operative delirium

	OR (95% CI)	p-value
CSA (reference: no SDB or OSA)	5.00 (1.41–17.80)	0.013
Age ⩾70 years	5.61 (1.79–17.63)	0.003
Male	1.27 (0.28–5.77)	0.757
BMI <25 kg·m^{-2}	4.03 (1.00–16.30)	0.051
Diabetes mellitus	1.20 (0.38–3.79)	0.753
Heart failure#	3.28 (1.05–10.29)	0.041
History of TIA or stroke	3.82 (0.98–14.85)	0.053
Anaemia¶	2.62 (0.78–8.83)	0.120
Renal failure+	1.47 (0.47–4.56)	0.507

CSA: central sleep apnoea; SDB: sleep disordered breathing; OSA: obstructive sleep apnoea; BMI: body mass index; TIA: transient ischaemic attack. #: N-terminal pro-brain natriuretic peptide ⩾450 pg·mL^{-1} (patients <50 years of age), ⩾900 pg·mL^{-1} (patients 50–<75 years of age) or ⩾1800 pg·mL^{-1} (patients ⩾75 years of age); ¶: haemoglobin <12 g·dL^{-1} (females) or <13 g·dL^{-1} (males); +: glomerular filtration rate <60 mL·min^{-1}·1.73 m^{-2}.

SDB starting with the first post-operative day (supplementary figure E2a). Remarkably, oxygen flow rates among patients with and without post-operative delirium were similar (supplementary figure E2b).

There was no significant difference in the post-operative administration of opioids or in the total post-operative morphine (intravenous) dose equivalent between the patients who experienced post-operative delirium compared with those without delirium (supplementary table E4).

The median (IQR) length of hospital stay was 9.0 (7.0–13.5) days for all patients. The median (IQR) length of hospital stay (12.0 (8.75–22.25) *versus* 9.0 (7.0–11.0) days; p<0.001) and time spent in the ICU/IMC setting (7.0 (4.0–9.0) *versus* 3.0 (2.0–6.0) days; p<0.001) were significantly longer for patients with delirium than for patients without delirium.

Discussion

This subanalysis of CONSIDER-AF provides novel insights into predictors of post-operative delirium in patients with and without SDB. First, 23% of all patients were diagnosed with post-operative delirium, and patients with CSA were significantly more likely to be affected by post-operative delirium than patients with OSA and patients without SDB. Second, CSA was independently associated with post-operative delirium. Third, length of hospital stay and time spent in the ICU/IMC setting were significantly longer for patients with post-operative delirium than for patients without delirium.

Incidence of post-operative delirium

According to CAM-ICU criteria, post-operative delirium was detected in 23% of patients. Our findings are in accordance with previous studies on patients undergoing cardiac surgery that have described post-operative delirium in 11–46% of patients [21]. Discrepancies in prevalence rates may be due to the heterogeneous use of delirium assessment tools as well as different patient characteristics (*e.g.* age and severity of heart disease) and surgical procedures (*e.g.* minimal invasive procedures or additional valve replacement). Consistent with previous reports, post-operative delirium was most frequently diagnosed on post-operative days 1 and 2 [22].

Predisposing risk factors for post-operative delirium

Prevention of post-operative delirium requires knowledge of the risk factors involved. To this end, various risk factors have been identified and advanced age ranks among the most established independent predictors for delirium after cardiac surgery [15]. In the present study, age ⩾70 years was associated with a four-fold increased incidence of post-operative delirium compared with those with a lower age. In this context, the increasing number of elderly patients undergoing cardiac surgery is clinically important [23], as many patients automatically fall into the category of patients with a higher risk of delirium.

Moreover, patients with cognitive impairment are at risk of developing post-operative delirium [24]. As symptoms may be subtle in milder forms of the disease, impaired cognition often remains undiagnosed [25]. Although no relevant impact of depression on post-operative delirium was found in the present study, a history of transient ischaemic attack or stroke was associated with post-operative delirium. This increased risk may be attributed to pre-existing cerebrovascular damage as well as to atherosclerotic carotid plaques and a higher peri-operative risk of cerebral embolisation during cannulation of the aorta [26].

In accordance with previous studies [14, 15], anaemia was found to be associated with post-operative delirium. Similar to low pre-operative oxygen saturation levels and peri-operative and post-operative hypoxaemia, anaemia may trigger post-operative delirium by contributing to decreased cerebral oxygenation in such patients [27]. Noninvasive ventilation is used in patients with hypoxia and hypercapnia after extubation, and may thus be associated with post-operative delirium, because cerebral hypoxia aggravates delirium and hypercapnia is attributable to drowsiness and hypoventilation [26].

Association of SDB with post-operative delirium

In the present study, CSA was associated with a more than five-fold increased risk of incident post-operative delirium. This association between CSA and post-operative delirium has been described in a case report by Becker *et al.* [28]: a patient with CSA and a clear manifestation of delirium had not improved until initiation of bilevel positive airway pressure therapy. In the present prospective observational study addressing the association between SDB and post-operative delirium, we differentiated between patients with CSA or OSA and patients without SDB. The previous studies available on this subject to date have only focused on patients with and without OSA or SDB (supplementary table E7). In a study by Flink *et al.* [14], post-operative delirium occurred in 25% of all patients undergoing elective knee arthroplasty. Post-operative delirium was experienced by 53% of patients with OSA compared with 21% of patients without OSA (p=0.0123). OSA was found to be the only statistically significant predictor of post-operative delirium in multivariable analyses [14]. The association between SDB and delirium after cardiac surgery has only been addressed in one prospective observational study conducted by ROGGENBACH *et al.* [15], who reported that a pre-operative AHI $\geqslant$19 events·h^{-1} was linked to an almost six-fold increased risk of incident post-operative delirium (p=0.001). Next to age, smoking and blood transfusion, pre-operative AHI has been independently associated with post-operative delirium in multivariable analyses [15].

The aforementioned studies were carried out in elderly patient cohorts [14, 15]. However, the study by FLINK *et al.* [14] included patients undergoing knee arthroplasty instead of cardiac surgery, and the procedures were conducted under both regional and general anaesthesia, which may limit the comparability of the results. Moreover, either no or only little specific information was given on the proportion of patients with heart failure [14, 15]. Although nowadays delirium prevention strategies are usually implemented in the ICU/IMC setting, no explanatory notes were given by FLINK *et al.* [14] and ROGGENBACH *et al.* [15] in this regard. A major limitation of the studies by FLINK *et al.* [14] and ROGGENBACH *et al.* [15] is the lack of information on the impact of CSA on post-operative delirium. FLINK *et al.* [14] focused on patients with OSA as identified by their medical records who had received polysomnography solely to confirm the diagnosis of OSA. The study by ROGGENBACH *et al.* [15] was conducted by means of portable SDB monitoring devices that were unsuitable for measuring thoracic breathing effort, and thus unable to differentiate between OSA and CSA.

Therefore, our study complements previous research in the following ways. In contrast to FLINK *et al.* [14] and ROGGENBACH *et al.* [15], recommended delirium prevention strategies were implemented in the routine post-operative management of patients. Remarkably, our findings show that only CSA is a strong predictor of delirium after cardiac surgery, whereas the incidence of post-operative delirium did not differ between patients with OSA and patients without SDB. Since CSA is less prevalent in the general population than OSA, it may have been neglected as a risk factor for post-operative delirium in previous analyses. However, approximately one-third of patients undergoing CABG surgery suffer from heart failure with reduced ejection fraction [29] and CSA is present in 31% of patients diagnosed with chronic heart failure [13]. CSA was an important pre-operative predictor for post-operative delirium independently of routine measures of heart failure severity and other important risk factors. All patients received supplemental oxygen. As supplemental oxygen reduces central apnoeas and hypopnoeas by 37–84% [30], the present observational study does not support the idea that the observed CSA-associated risk for post-operative delirium can be reduced by supplemental oxygen in the peri- and post-operative phases.

Pathophysiology

The present observational study cannot prove a causal relationship between CSA and post-operative delirium. However, recent studies suggest that regular intermittent hypoxia may trigger vascular dysfunction, neuronal loss and impair the blood–brain barrier, which might ultimately cause long-term disruption of the brain's microenvironment and synaptic plasticity [31–33]. Moreover, findings have to be interpreted in the context that there is a bidirectional relationship between CSA and heart failure [1, 7], which is an established risk factor for post-operative delirium. CSA may worsen post-operatively due to cardiac dysfunction, fluid overload and pulmonary congestion triggering instability of ventilator control after CABG surgery [6, 8]. In reverse, CSA may promote worsening of heart failure by exposing the heart to intermittent hypoxia, sympathetic activation as well as oscillations of heart rate and blood pressure [10, 34].

Post-operative delirium, post-operative outcome and in-hospital treatment costs

In the present study, patients with post-operative delirium required prolonged in-patient treatment. Presence of post-operative delirium extended the time spent in the ICU/IMC setting by 4 days and the duration of hospitalisation by 3 days compared with patients without delirium. This finding is consistent with the studies by ROGGENBACH *et al.* [15] and BROWN *et al.* [5], in which the diagnosis of post-operative delirium after cardiac surgery had significantly increased the time spent in the ICU/IMC setting from 4 to 6 days [15] and the length of hospital stay from 7 to 9 days [5].

Several reasons have been identified that may increase the duration of hospitalisation for patients with post-operative delirium. Delirious patients are often not only restrained due to hypoactive behaviour or the administration of drugs [35], but are also impaired in their mobility, a factor that is increasingly recognised as being essential for recovery [36]. Patients with post-operative delirium are prone to iatrogenic infections from additional monitoring and prolonged use of central venous or urinary catheters [5]. Although it may be tempting to speculate that prolonged hospitalisation could be attributed to higher comorbidity rates among patients with post-operative delirium, systematic reviews and meta-analyses have not yielded any relevant influence of demographic parameters or comorbidities on the independent association between post-operative delirium and prolonged length of hospital stay [37].

As daily costs of a bed in an ICU in Europe range from EUR1168 to EUR2025, prolongation of hospitalisation ties up substantial financial resources [38]. In-hospital treatment costs for patients with incidental delirium were reported to be at least EUR1300 higher than for patients without delirium [5, 39]. As post-operative delirium is considered a modifiable risk factor for prolonged length of hospital stay, patients at high risk have to be identified early on.

Clinical implications

Although SDB is a common disorder among patients undergoing cardiac surgery, the majority of patients affected by SDB remain undiagnosed [40]. Our findings support recommendations to incorporate systematic identification of patients with SDB into the routine pre-operative risk assessment of patients scheduled for cardiac surgery. According to current guidelines on SDB and peri-operative management [41, 42], all patients should be pre-operatively assessed for their risk of SDB. Elective patients with a high pre-test probability of SDB should undergo thorough SDB screening before surgery [42]. According to current guidelines [43], effective prevention strategies should be implemented in the routine peri-operative care of patients undergoing cardiac surgery to minimise the incidence of delirium and its adverse outcomes. Approximately 30–40% of all cases of post-operative delirium are considered preventable [44]. Even more cases may be prevented by detecting CSA and established risk factors as well as by intensified implementation of effective prevention strategies in patients with a high risk of post-operative delirium.

Limitations

Although polysomnography is considered the gold standard for diagnosing SDB, a portable SDB monitoring device was used in this study. Recent studies have shown good sensitivity and specificity of portable SDB monitoring devices in diagnosing OSA [45], but diagnostic accuracy for CSA is less well investigated. The clearly different results for OSA and CSA indicate a low rate of misclassification, since misclassification would confer a conservative bias and may contribute to missing differences between OSA and CSA. Pre-operative cognitive function was not assessed with standardised tools, although cognitive impairment has previously been linked to post-operative delirium [8], which might confound our findings. The present observational study cannot prove a causal relationship between CSA and post-operative delirium. Results have to be interpreted in the context that the severity of heart failure may contribute to the severity of CSA.

Conclusions

This study emphasises that post-operative delirium is a multifactorial disease that affects approximately one-quarter of patients undergoing cardiac surgery. CSA was shown to be independently associated with delirium. Our findings contribute to facilitating the pre-operative identification of patients at high risk of developing delirium after cardiac surgery. The implementation of intensified delirium prevention strategies into the peri-operative management of such patients may improve post-operative outcome.

Author contributions: M. Tafelmeier, S. Wagner and M. Arzt were involved in the conception, hypotheses delineation, study design, data acquisition, analysis and interpretation of such information, and in writing the article and its revision prior to submission. M. Knapp and S. Lebek were involved in the data collection and interpretation as well as in the revision of the article prior to submission. F. Zeman was involved in the statistical analysis, interpretation of such information and in the critical revision of the article prior to submission. B. Floerchinger, D. Camboni, S. Wittmann, C. Schmid and L.S. Maier were involved in the interpretation of the data and in the revision of the article prior to submission. M. Tafelmeier and M. Arzt have been identified as the guarantors of the paper and take responsibility for the integrity of the work as a whole from inception to published article.

Conflict of interest: M. Tafelmeier reports grants from Philips Respironics and the Medical Faculty of the University of Regensburg, during the conduct of the study. M. Knapp has nothing to disclose. S. Lebek has nothing to disclose. B. Floerchinger has nothing to disclose. D. Camboni has nothing to disclose. M. Creutzenberg has nothing to disclose. S. Wittmann has nothing to disclose. F. Zeman has nothing to disclose. C. Schmid has nothing to disclose. L.S. Maier has nothing to disclose. S. Wagner has nothing to disclose. M. Arzt reports grants and personal fees for lecturing from Philips Respironics and ResMed, during the conduct of the study.

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