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ORIGINAL ARTICLE

Anaesthesia care team improves outcomes in surgical patients compared with solo anaesthesiologist

An observational study

Philippe Dony, Laurence Seidel, Magali Pirson and Patrice Forget

BACKGROUND In anaesthesiology, little attention has been drawn to the role of anaesthesia nurses as support personnel on quality of care.

OBJECTIVES To compare an anaesthesiologist alone (solo anaesthesiologist) with an anaesthesia care team (anaesthesiologist and anaesthesia nurse).

DESIGN An observational study.

SETTING A single centre study.

PARTICIPANTS Anaesthesiologists and anaesthesia nurses.

INTERVENTION Anaesthesia performed by solo anaesthesiologists compared with anaesthesia care teams.

MAIN OUTCOME MEASURES 30-day postoperative mortality and hospital length of stay. Propensity score matching was performed by logistic regression to adjust for baseline differences between the two groups and pairs of perfectly matched patients were formed.

RESULTS Anaesthesia was performed by solo anaesthesiologists in 2832 patients and by an anaesthesia care team in 2842 patients. Matching with 2095 pairs of perfectly matched patients was formed. The two groups were comparable in respect of sex and duration of anaesthesia but differed notably for age, American Society of Anesthesiologists' physical status score and type of surgery. Logistic regression showed a significantly lower 30-day mortality rate for the anaesthesia care teams compared with solo anaesthesiologists (0.76 vs. 1.56%, $P = 0.0014$). Length of hospital stay was also significantly reduced when an anaesthesia nurse was present (4.9 ± 10.1 vs. 5.6 ± 11.5 days, $P = 0.0011$).

CONCLUSION Anaesthesia given by teams of anaesthesiologists and anaesthesia nurses is associated with decreased 30-day postoperative mortality and shorter length of stay when compared with solo anaesthesiologists. Even without any demonstration of causality, this emphasises the benefits of the anaesthesia care team model.

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Introduction

In anaesthesiology, research has mainly focused on equipment and techniques leading to safer practice. Little attention has been paid to the role of support personnel, in particular anaesthesia nurses, on quality of care. There are major differences in the organisation of anaesthesia care teams across Europe and internationally, where anaesthetics may be administered by the anaesthesiologist individually or as part of an anaesthetic team.[1–3] In a recent review on the safety of different anaesthetic providers, Lewis *et al.*[4] concluded that no definitive statement can be made about the superiority of one type of anaesthesia care over another. The study of the Anesthesia Society of Minnesota showed a significant association between a better patient outcome and the presence of a 'nurse anaesthetist' commonly called 'certified registered nurse anaesthetist' in the United States of America (USA) supervised by an anaesthesiologist during anaesthesia and a better patient outcome.[5] Thus, despite the widespread desire and endeavours of anaesthesiologists to dispose of skilled and qualified nursing

Department of Biostatistics, University Hospital of Liège, Liège (LS), Health Economics, Health Facility Administration and Nursing Science, Ecole de Santé publique, Université Libre de Bruxelles (PD, MP) and Anaesthesiology and Perioperative Medicine, Vrije Universiteit Brussel (VUB), Universitair Ziekenhuis Brussel (UZ Brussel), Brussels, Belgium (PF)

Correspondence to Patrice Forget, Anaesthesiology and Perioperative Medicine, Vrije Universiteit Brussel (VUB), Universitair Ziekenhuis Brussel (UZ Brussel), Laarbeeklaan 101, 1090 Brussels, Belgium
Tel: +32 24773058; e-mail: forgetpatrice@yahoo.fr

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help during anaesthesia, no scientific evidence in the Minnesota study has been provided to demonstrate that this additional help could be beneficial for patient safety. Large-scale data regarding the specific impact of anaesthesiologist intervention on surgical outcome are scarce, yet the delivery of anaesthesia services provides a unique opportunity to observe the influence of provider mix on outcomes in a complex medical environment. Thus, the question remains as to whether support by an anaesthesia nurse, at least as it is understood in the European clinical environment, could influence outcome, specifically peri-operative mortality. In this study, we focused on two outcomes, 30-day postoperative mortality and hospital length of stay (LOS). Peri-operative mortality (during and after operation) reflects at least partially unsafe practices or poor quality of peri-operative care, whereas LOS is associated with postoperative complication rates.[6] As a large proportion of postoperative deaths occur after hospital discharge, mortality was recorded up to 30 days as recently suggested by different authors.[7,8] The current study evaluated the impact of anaesthesia by the anaesthesiologist alone (solo anaesthesiologist) or in combination with an anaesthesia nurse (anaesthesia care team) on 30-day postoperative mortality as well as on LOS.

Material and methods

The current retrospective observational study is reported according to the 'REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement',[9] and an extension of guidelines reporting items specific to observational studies using routinely collected health data 'STrengthening the Reporting of OBservational Studies in Epidemiology guidelines'. The methodology was evaluated by applying the RECORD checklist[10] (Supplementary Data Content 1, http://links.lww.com/EJA/A176). The study was conducted in a single clinical centre and approved by the ethics committee of the institution (no. CCB 325201730849). The study material consisted of an initial sample of 14 237 consecutive surgical procedures under general or locoregional anaesthesia performed between 1 January 2015 and 17 July 2016 on 12 135 patients. Anaesthesia procedures before 2015, relating to paediatric interventions, with missing values, containing outliers regarding the potential predictors or duplicates had been previously discarded. The presence/absence of an anaesthesia nurse supervised by the attending anaesthesiologist in the operating theatre (in Belgium, anaesthesia nurses must be supervised by an anaesthesiologist at all times) was recorded for each procedure. Cases in which an anaesthesiology resident was directed by an attending anaesthesiologist were also known. Thus, anaesthesia was performed by a solo anaesthesiologist in 3373 interventions, by an anaesthesiologist and an anaesthesiology resident in 7740 interventions, by an anaesthesiologist and anaesthesia nurse (anaesthesia care team) in 3367 interventions and by an anaesthesiologist with an anaesthesiology resident and an anaesthesia nurse in 57 interventions. However, this study focused only on the last anaesthesia procedure conducted on each patient by a solo anaesthesiologist (2832 patients) or anaesthesia care team (2842 patients), yielding a total of 5674 procedures.

The procedures were extracted from the local anaesthesia data warehouse in routine use since 2015. The data warehouse assembles information from three distinct sources: the anaesthesia information management system developed in-house and fully integrated in the electronic health record (EHR) which collects peri-operative data; the hospital management system recording administrative data; and the hospital information system providing the medical data captured in the EHR including patient outcome (death/survival). A detailed description of data sources is given in Supplementary Data Content 2, http://links.lww.com/EJA/A176.

The following data were available for each patient: age, sex, American Association of Anaesthesiologists' (ASA) physical status (1 to 4), type of surgery (cardiothoracic, maxillofacial, plastic, vascular, visceral, gastroenterological, gynaecological, neurosurgical, ear–nose–throat, ophthalmological, orthopaedic, urological or other), 30-day outcome (survival/death) and cause of death. The duration of anaesthesia was also known. This study focused on two end points: 30-day outcome (death or survival) in which in-hospital mortality was defined as death within 30 postoperative days but before discharge (retrieved from patient records) and deaths after hospital discharge (captured from the national social security register, Brussels, Belgium); and hospital LOS collected from hospital administrative records of the patient.

Statistical methods

Results of quantitative variables were summarised as mean ± SD. Frequency tables were used for categorical variables. The correlation coefficient measured the association between two quantitative variables. Mean values were compared by one-way analysis of variance and proportions by the χ^2 test. Logistic regression was used to construct a propensity score for matching patients of the two groups (solo anaesthesiologist and anaesthesia care team) to adjust for baseline differences. Patients were matched one-by-one with a calliper width of 0.0025. Specifically, the 0 to 1 propensity score interval was divided into 400 classes of equal length. The incidence of 30-day mortality was recorded in the matched groups and the adjusted relative risk (RR) calculated by the Cochran–Mantel–Haenszel method. Length of hospital stay between matched patients was compared by the Wilcoxon signed-rank test. LOS curves were displayed graphically by the Kaplan–Meier method. Stratified Cox regression analysis was applied to matched pairs to calculate the adjusted hazard ratio with 95% confidence interval (CI). Results were considered significant at the 5% critical level ($P < 0.05$). All statistical calculations were performed

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Table 1 Characteristics of 'solo anaesthesiologist' and 'anaesthesia care team' groups

Variable	Category	Solo anaesthesiologist, *N*=2832	Anaesthesia care team, *N*=2842	*P*
Age (years)		51.6 ± 19.3	50.5 ± 18.3	0.033
Sex				
	Female	1588 (56.1)	1651 (58.1)	0.12
	Male	1244 (43.9)	1191 (41.9)	
ASA-PS				
	1	705 (24.9)	822 (28.9)	<0.0001
	2	1450 (51.2)	1526 (51.3)	
	3	604 (21.3)	474 (16.7)	
	4	73 (2.6)	20 (0.70)	
Surgery	Visceral	460 (16.2)	640 (22.5)	<0.0001
	Gynaecology	470 (16.6)	564 (19.8)	
	Orthopaedics	437 (15.4)	454 (16.0)	
	Neurosurgery	370 (13.1)	139 (4.9)	
	Urology	158 (5.6)	270 (9.5)	
	Cardiothoracic	313 (11.1)	73 (2.6)	
	Maxillofacial	184 (6.5)	181 (6.4)	
	Vascular	191 (6.7)	150 (5.3)	
	ENT	93 (3.3)	119 (4.2)	
	Plastic	53 (1.9)	98 (3.4)	
	Gastroenterological	42 (1.5)	89 (3.2)	
	Ophthalmology	31 (1.1)	24 (0.8)	
	Other	30 (1.1)	41 (1.4)	
Duration of anaesthesia (min)		113 ± 88.4	106 ± 74.6	0.56

Values are mean ± SD or number (%). ASA-PS, American Society of Anesthesiologists' physical status; ENT, ear–nose–throat.

with SAS (version 9.4, Cary, NC, USA) and R (version 3.3.3, Vienna, Austria) software packages.

Results

Patients' characteristics in the two study groups are shown in Table 1. The groups differed in respect of age, ASA physical status and type of surgery, but were comparable for sex and duration of anaesthesia. There were less anaesthesia care team procedures than solo anaesthesiologist procedures for high-risk (ASA 3 to 4) patients (17.4 vs. 23.9%). The presence of an anaesthesia nurse was also less frequent for neurosurgical (139/509, 27.3%) and cardiothoracic (73/386, 18.9%) surgical procedures compared with other interventions, where it ranged between 43.6% (ophthalmology) and 67.9% (abdominal surgery). Anaesthesiologists of the solo group were slightly but significantly younger than those of the anaesthesia care team group (47.1 ± 10.3 vs. 48.6 ± 9.1 years; $P < 0.0001$). As far as end points are concerned, Table 2 shows that 30-day mortality was significantly lower in the anaesthesia care team group than in the solo anaesthesiologist group (0.67 vs. 2.12%, $P < 0.0001$). Similarly, LOS was also significantly reduced in the former group (4.9 ± 9.8 vs. 6.3 ± 11.6 days, $P < 0.0001$).

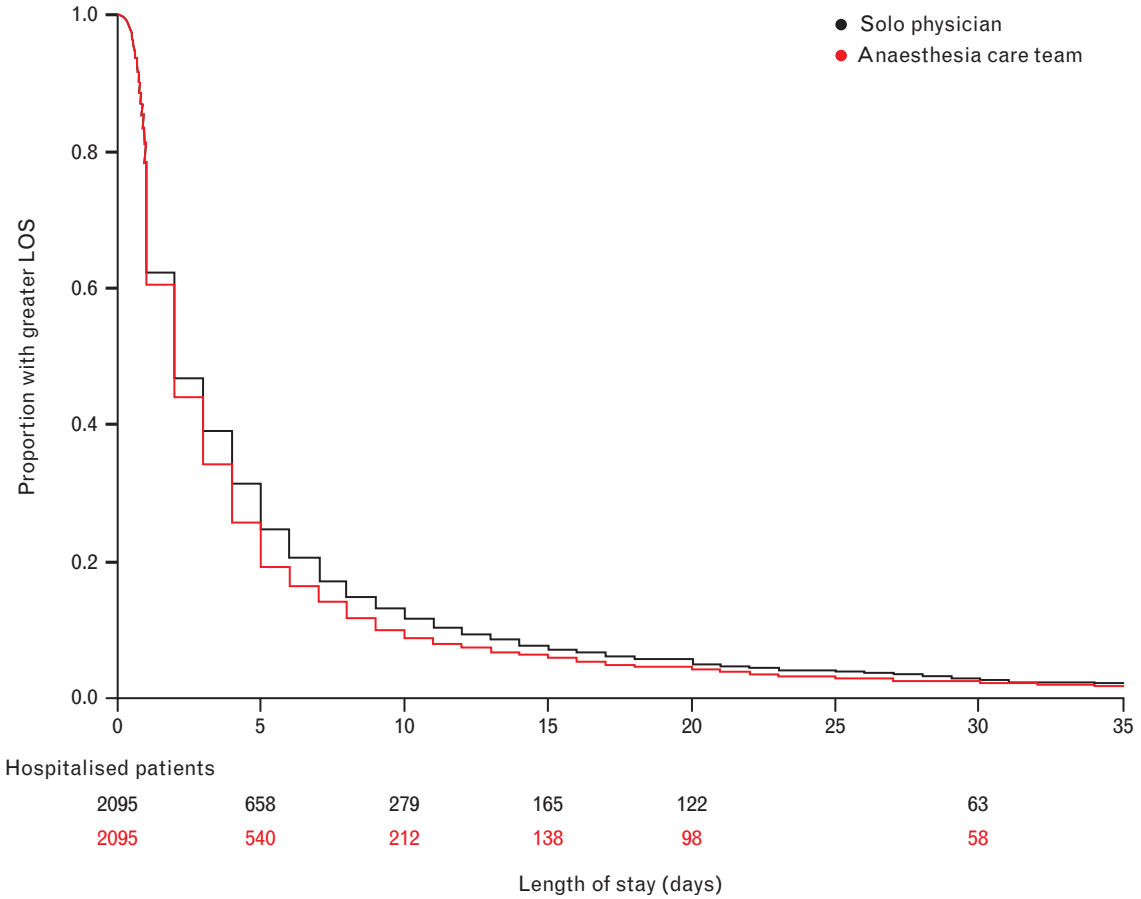
To account for potential confounding factors, biases and baseline differences, a propensity score matching (PSM) procedure was applied to the two groups by logistic regression analysis. PSM was based on age, sex, ASA score, duration of anaesthesia and type of surgery. Then patients of the two groups were matched one-by-one using a calliper width of 0.0025 as described in the statistical section yielding a total of 2095 matched pairs (solo anaesthesiologist, anaesthesia care team) out of a maximum of 2832 possibilities (i.e. 73%). The total number of 30-day deaths decreased from 79 to 49, corresponding to a loss of 38%. To test the quality of the matching, solo anaesthesiologist and anaesthesia care team matched patients were compared for each variable used in the PSM. No differences were observed between the two groups, indicating a satisfactory

Table 2 Comparison of 30-day mortality and hospital length of stay between solo anaesthesiologist and anaesthesia care team procedures

Endpoint	Solo anaesthesiologist		Anaesthesia care team		Risk (95% CI)	*P*
30-day mortality						
	N	Number (%)	*N*	Number (%)		
All patients	2832	60 (2.12)	2842	19 (0.67)	RR 3.17 (1.90 to 5.29)	<0.0001
PSM patients	2095	33 (1.58)	2095	16 (0.76)	RR 2.06 (1.14 to 3.74)	0.015
LOS (days)						
	N		*N*	Mean ± SD		
All patients	2832	6.3 ± 11.6	2842	4.9 ± 9.8	HR 1.18 (1.12 to 1.24)	<0.0001
PSM patients	2095	5.6 ± 11.5	2095	4.9 ± 10.1	HR 1.10 (1.03 to 1.17)	0.0011

Values are mean ± SD or number (%). CI, confidence interval; HR, hazard ratio; LOS, length of stay; PSM, propensity score matching; RR, relative risk.

Fig. 1



Kaplan–Meier curves for hospital length of stay in 2095 matched patients of solo anaesthesiologist and anaesthesia care team groups (hazard ratio 1.10, 95% confidence interval 1.03 to 1.17; $P < 0.0001$).

matching (Supplementary Data Contents 3 and 4, http://links.lww.com/EJA/A176).

There were 33 deaths (1.56%) recorded in the solo anaesthesiologist group and 16 (0.76%) in the anaesthesia care team matched group, yielding a RR of 2.06 (95% CI 1.14 to 3.74, $P = 0.014$) (Table 2). Thus the presence of an anaesthesia nurse was associated with a 50% reduction in risk of 30-day mortality compared with solo anaesthesiologist procedures.

The hospital LOS was 5.6 ± 11.5 days in the solo anaesthesiologist group and 4.9 ± 10.1 days in the anaesthesia care team matched group ($P = 0.0011$) (Table 2). This significant reduction was confirmed by Cox regression analysis for stratified data (hazard ratio 1.10, 95% CI 1.03 to 1.17). LOS Kaplan–Meier survival curves (Fig. 1) show that the proportions of patients still hospitalised after 5, 10, 15, 20, 30 and 40 days in solo anaesthesiologist vs. anaesthesia care team were 24.9 vs. 19.4%, 11.8 vs. 8.9%, 7.3 vs. 5.9%, 5.2 vs. 4.3%, 2.8 vs. 2.6% and 1.6 vs. 1.8%, respectively.

Discussion

There were two salient findings in this study regarding the anaesthesia care team compared with a solo anaesthesiologist: lower 30-day postoperative mortality and shorter hospital LOS. Given the apparent difference in the prevalence of comorbidities, adequate adjustment was important. The higher mortality after solo anaesthesiologist procedures may be explained by 'two heads are better than one'. One might reasonably expect that this model would prove to be safer and that having two skilled people at hand when an unexpected mishap occurs produces a better result. Several studies have addressed the question of whether a significant outcome difference can be discerned in surgical patients in which anaesthesia care was personally performed or medically directed by an anaesthesiologist.[4,11–14]

The present findings about 30-day mortality are in line with those of a previous study about the relative safety of anaesthesiologists and nurse anaesthetists.[5] The authors concluded that the mortality following surgery in which

anaesthesia was administered by either an anaesthesiologist or an anaesthesia nurse was much the same, but when there was a mixed system, the outcome was significantly better. They called their mixed model the anaesthesia team. The replacement of the concept of assistance by the concept of a team is relatively recent and bears two different meanings. In the USA, it means one anaesthesiologist supervising two or more assistants giving general anaesthesia. In Belgium, it concerns an assistant (e.g. anaesthesia nurse) working with an anaesthesiologist with only one patient being anaesthetised. It coincides with the changing role of the anaesthesiologist, who has now come to be referred to as a peri-operative physician.[15]

However, the overall reduction of hospital LOS observed in the anaesthesia care team patients compared with a solo anaesthesiologist after PSM matching is novel. The fact that this reduction was statistically significant may be explained by the large sample size in both groups but the age question remains of clinical relevance. A decrease of about half a day was noted between the two groups (from 5.6 ± 11.5 days for solo anaesthesiologist to 4.9 ± 10.1 days for anaesthesia care team) after PSM. This difference strongly supports the idea of a beneficial influence of the presence of anaesthetic nurses besides the anaesthesiologist during procedures. Modern peri-operative care including that provided by anaesthesiologists and anaesthesia nurses often prevents immediate postoperative mortality. Further, there is increasing evidence that anaesthetic practice influences subsequent patient outcomes in ways that were not recognised previously. Even relatively simple measures, such as maintaining normothermia or supplementing oxygen in the peri-operative period, can decrease the incidence of subsequent morbid events, including cardiac morbidity and postoperative wound infection.[16,17] Thus, assistance provided to the anaesthesiologist may be beneficial in other situations than just work overload, although this cannot be formally established by the current study. As anaesthesia technician positions do not exist in Belgium, anaesthesia nurses perform a number of tasks that technicians would do in the USA system. Their assistance to the anaesthesiologist is usually limited to induction and recovery whenever necessary but anaesthetic nurses can occasionally provide help upon the surgeon's demand. The Belgian system requests that an anaesthesiologist should be present at every anaesthesia procedure and that simultaneous interventions are not allowed. Although the training of anaesthesia nurses is established in Belgian nursing schools, their official recognition as a specialised profession is still awaited.

Our study has some limitations. It is a single-centre study in which surgeons and anaesthesiologists have their own way of practising and clinical habits which may differ from other institutions. The respective impact of surgeons and anaesthesiologists on study outcomes is hard to disentangle. Further, the allocation of anaesthesia nurses to surgical interventions may also be different in other hospitals, although in our clinical institution the study data do not provide a clear vision of how this allocation is done. Is it merely based on anaesthesia nurse availability at the time of planning the procedures? The presence of an anaesthesia nurse was less frequent in neurosurgical and cardiothoracic surgical procedures, and also more generally in interventions on high-risk (ASA 3 to 4) patients.

It may be claimed that anaesthesia nurses were appointed to assist less experienced anaesthesiologists but our study did not support this assumption; indeed anaesthesiologists in the care team group were slightly older than those in the solo group and therefore, in principle, more experienced. The PSM procedure reduced the initial sample size by 25% but this is the price to pay to eliminate baseline differences between the two groups as much as possible. Despite stringent one-to-one matching of patients, our findings are not exempt of any remaining hidden and/or structural bias affecting the inclusion or not of an anaesthetic nurse in the anaesthesia team. For example, surgical categories used in the study were broad classes and a detailed classification of procedures would have been more appropriate. This has probably impacted the propensity score approach in the sense that, within a single surgical category, matched patients may have undergone quite different operations. In Belgium, aid and assistance to the anaesthesiologist is not permanent, but for induction, recovery and as required if necessary. During surgery, the same nurse must help the surgeon and assist the anaesthesiologist if necessary. An anaesthesiologist is present at every anaesthesia procedure and simultaneous care of more than one patient is not allowed. Although training was available for the anaesthesia nurse, much remained to be done in that area to have access to specialised personnel. In our centre, we have a few extra anaesthesia nurse to help a few doctors. Their distribution is most often to accelerate the activity of a younger doctor's supervision in a different operating room. The presence of an anaesthesia nurse was less frequent in neurosurgical and cardiothoracic surgical procedures, and also more generally in interventions on high-risk patients.

The retrospective survey is also descriptive and not mechanistic. Further studies, possibly based on randomised control trials, are required to verify results by considering potential confounding factors, such as case-mix and comorbidity. More extensive work involving individual chart review may be helpful for exploring these questions. The influence on outcome of other factors, such as complexity of the interventional procedure or emergency intervention, will have to be investigated.[6,18–21]

In conclusion, results of the present retrospective study show that the risk of 30-day death and hospital LOS are substantially lower if an anaesthesia nurse is present and supervised by an anaesthesiologist, compared with a solo

anaesthesiologist. The research shows an interesting association. However, it cannot give any clear indication as to what is correlation and what is causation.

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