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Original Article

General anaesthetic and airway management practice for obstetric surgery in England: a prospective, multicentre observational study*

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Summary

There are no current descriptions of general anaesthesia characteristics for obstetric surgery, despite recent changes to patient baseline characteristics and airway management guidelines. This analysis of data from the direct reporting of awareness in maternity patients' (DREAMY) study of accidental awareness during obstetric anaesthesia aimed to describe practice for obstetric general anaesthesia in England and compare with earlier surveys and best-practice recommendations. Consenting patients who received general anaesthesia for obstetric surgery in 72 hospitals from May 2017 to August 2018 were included. Baseline characteristics, airway management, anaesthetic techniques and major complications were collected. Descriptive analysis, binary logistic regression modelling and comparisons with earlier data were conducted. Data were collected from 3117 procedures, including 2554 (81.9%) caesarean deliveries. Thiopental was the induction drug in 1649 (52.9%) patients, compared with propofol in 1419 (45.5%). Suxamethonium was the neuromuscular blocking drug for tracheal intubation in 2631 (86.1%), compared with rocuronium in 367 (11.8%). Difficult tracheal intubation was reported in 1 in 19 (95%CI 1 in 16–22) and failed intubation in 1 in 312 (95%CI 1 in 169–667). Obese patients were over-represented compared with national baselines and associated with difficult, but not failed intubation. There was more evidence of change in practice for induction drugs (increased use of propofol) than neuromuscular blocking drugs (suxamethonium remains the most popular). There was evidence of improvement in practice, with increased monitoring and reversal of neuromuscular blockade (although this remains suboptimal). Despite a high risk of difficult intubation in this population, videolaryngoscopy was rarely used (1.9%).

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Introduction

Neuraxial anaesthesia is the preferred technique for most obstetric surgical procedures [1], but general anaesthesia (GA) is still required in some clinical situations. The provision of general anaesthesia in obstetric patients remains a source of controversy, with concerns about increased risks of failed intubation and accidental awareness during general anaesthesia (AAGA) and the impact on maternal experience [2–4].

The 5th National Audit Project (NAP5) of the Royal College of Anaesthetists and the Association of Anaesthetists investigated AAGA. Both the primary investigation [1] and the activity survey [3] highlighted some of the unique challenges associated with general anaesthesia in obstetrics, and also some of the idiosyncrasies of practice in this area compared with the provision of general anaesthesia outside obstetrics [1, 3].

The direct reporting of awareness in maternity patients (DREAMY) study was a multicentre, prospective cohort study that aimed to establish the incidence, risk-factors and sequelae of AAGA in obstetrics [5]. A secondary study was embedded within it with the aim of describing general anaesthesia practice in obstetric patients in the UK. Specifically, this study aimed to examine the choice of drugs and airway management techniques and evaluate any change in practice since NAP5 [1].

Methods

This investigation was planned as a descriptive cross-sectional study of general anaesthesia characteristics for patients recruited to the DREAMY study. Research Ethics Committee and Health Research Authority approval was granted. Full details of the DREAMY study protocol are available separately [5]. This account follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for reporting observational studies [6].

Recruitment took place in NHS hospitals in England between May 2017 and August 2018. Data were collected from patients undergoing general anaesthesia for obstetric surgery, provided the following inclusion criteria were met: written consent; age ≥ 18 y; and surgery with an obstetric indication occurring at ≥ 24/40 weeks of gestation to < 48 h postpartum. Pregnant patients who received general anaesthesia for a non-obstetric indication (e.g. colorectal surgery) were not included, nor were patients who were too unwell to participate in the AAGA interview components of the primary study and those unable to communicate in English. The study was supported by an affiliated anaesthetic trainee research network, the Pan-London Perioperative Audit and Research Network (PLAN). Collaborations with anaesthetic trainee networks outside London were invited.

Aspects of general anaesthesia conduct that were evaluated included: indications for general anaesthesia; the training grade of the most senior anaesthetist present; time and duration of general anaesthesia; and anaesthetic induction technique (use of rapid sequence induction). Anaesthetic pharmacological data included: choice and dose of induction agent; maintenance agent; neuromuscular blocking (NMB) drug; and use of NMB reversal agent.

Data on airway management included direct laryngoscopic view, based on a modified version of the original Cormack and Lehane grading [7, 8]. The primary airway device used, difficulties with airway management and intubation technique (including videolaryngoscopy or awake tracheal intubation) were recorded. Data were collected on critical incidents that included regurgitation, aspiration and critical care admission.

Difficult intubation was defined as a clinical situation in which the most senior anaesthetist present required multiple (≥ 2) attempts, or was unable to successfully intubate the trachea, or if difficult intubation was recorded on the anaesthetic chart as the subjective opinion of the anaesthetist.

Baseline characteristics included: age of patient; parity; ASA physical status; booking weight; height; and BMI. The surgical procedure was recorded as caesarean section (CS); exploration under anaesthesia; manual removal of placenta; or specified individually according to the procedure undertaken. Urgency of CS was classified in accordance with the model proposed by Lucas et al. [9] and adopted by the Royal College of Obstetricians and Gynaecologists in the UK using categories 1–4: category 1 representing surgery needed due to immediate threat to life of the mother or baby to category 4, elective surgery. The urgency of non-CS procedures was classified using the NCEPOD model (immediate, urgent, expedited, elective) [10]. Results were presented separately for CS and non-CS procedures for ease of comparison with previous and future surveys of obstetric practice.

All data were collected via an online secure database [11]. The sample size was determined by the primary outcome in the DREAMY study. Continuous variables were compared using independent *t*-tests or Wilcoxon rank-sum tests, as determined by assessing normality of sample data distribution with Shapiro-Wilk testing. Categorical variables were analysed using chi-squared or Fisher's exact test.

Binary logistic regression analysis was performed to identify independent factors that influenced induction hypnotic drug choice and airway complications. All significant covariates after univariate testing were entered into a multivariable logistic regression analysis. Hospitals were grouped and analysed according to Health Education England anaesthetic training regions, which were expected to provide a balance between geographic distribution and relative homogeny of practice. Odds ratio (OR) with 95%CIs were used to quantify effect sizes. Significance was estimated with the Wald test. All statistical analyses were performed using SPSS software (version 25, IBM, Armonk, NY, USA).

Results

A total of 3115 patients provided written informed consent for inclusion following eligibility screening of 4969 patients. Participation included 72 (45.6%) of the 158 NHS hospitals where obstetric anaesthesia services are offered in England, although patient recruitment was weighted towards London and southern England (Fig. 1, online Supporting Information Table S1). Hospitals included teaching hospitals (22) and district general hospitals (50), although all provided labour ward and obstetric operating theatre facilities. The median (IQR [range]) number of patients recruited at each site was 37 (25–59 [3–146]). Four patients underwent two recorded general anaesthetics during their inpatient stay with both anaesthetic episodes included, and two patients had no anaesthetic data reported; hence the total number of general anaesthesia episodes for data analysis was 3117 (Fig. 1).

Baseline characteristics of included patients are provided in Table 1. Data for patients who received general anaesthesia for obstetric surgery were different from national baseline maternity patient statistics [12, 13]. Patients receiving general anaesthesia were slightly older; mean (95%CI) difference 1.0 years (0.79–1.20) years, $p < 0.01$ and more likely to be primigravid; difference 18.3 (15.7–19.1) %, $p < 0.01$. Women with BMI $\geq$ 30 kg.m^{-2} were marginally over-represented; mean (95%CI) difference 3.1 (1.6–4.6) %, $p < 0.01$ (Table 1).

A total of 2554 general anaesthetics (81.9%) were undertaken for CS, of which 1329 (42.6%) were classed as category 1. Most general anaesthetics were initiated before initial surgical incision, although a minority were converted to general anaesthesia after surgery had started, typically due to inadequate neuraxial block (Table 2). The median (IQR [range]) duration of surgery was 60 (45–75 [6-390]) min.

Rapid sequence induction (RSI) was the preferred anaesthetic induction technique for almost all patients, used in 3099 (99.4%). Thiopental was the most used hypnotic drug for induction of general anaesthesia, used in 1649 (52.9%) (Table 3). Propofol was used for induction in 1419 (45.5%) and ketamine was the primary induction drug in 28 (0.9%). Two patients received etomidate as their primary induction hypnotic drug. One patient received thiopental followed by additional boluses of propofol during induction of general anaesthesia. One patient with severe needle phobia had inhalational induction with sevoflurane and cricoid pressure, followed by intravenous access and administration of additional intravenous hypnotic drugs. In most of the patients, maintenance of general anaesthesia was with volatile agents (Table 3; Figure 2).

Non-CS surgery was more likely to be associated with propofol induction; OR (95%CI) 1.90 (1.51–2.39). Patients who had less urgent surgery were more likely to have propofol (rather than thiopental) as the urgency of surgery reduced from 'immediate' to 'elective'; OR (95%CI) 1.19

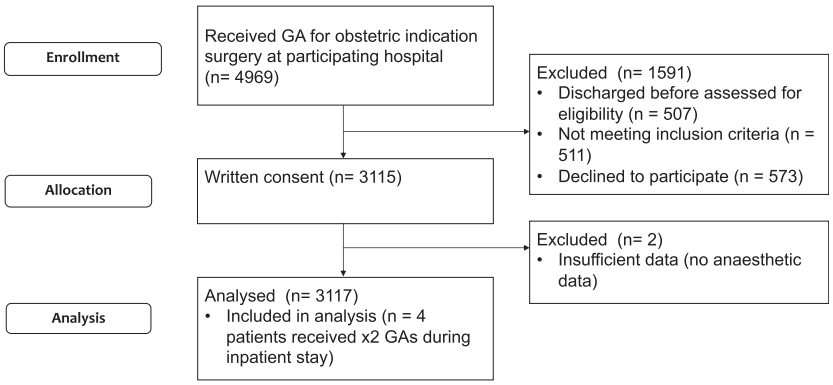

Figure 1 Study flowchart of patient recruitment. GA, general anaesthetic.

Table 1 Baseline characteristics of included patients, all of whom received general anaesthesia for obstetric surgery. Values are mean (SD), median (IQR [range]) or number (proportion). Weights were recorded at the time of pregnancy booking appointment. Healthy pregnant women were defined as ASA physical status 1 for the purposes of this study.

Characteristic	All patients n = 3115	National data for maternity patients	National data source
Age; y	31.5 (6.1)	30.5 (5.5)	ONS[a]; 2017; England and Wales; n = 679,106
Weight; kg	70 (60.8–84 [38–188])	N/A	ONS[a]; 2017; England; n = 451,929
BMI; $kg.m^{-2}$	27.7 (6.1)	N/A	MSDS[b]; 2018; England; n = 398,026
< 18.5	53 (1.7%)	N/A	
≥ 18.5–< 25	978 (31.4%)	45.8%	
≥ 25–< 30	716 (23.0%)	26.5%	
≥ 30	737 (23.7%)	20.6%	
≥ 35	338 (10.9%)	5.0%	
Unknown	293 (9.4%)	–	
Parity			MSDS[b]; 2018; England; n = 398,026
1	1842 (59.1%)	41.7%	
2	724 (23.2%)	35.4%	
3	290 (9.3%)	14.0%	
≥ 4	214 (6.9%)	8.7%	
Unknown	45 (1.4%)	–	
ASA physical status		N/A	N/A
1	1219 (39.1%)		
2	1598 (51.2%)		
3	205 (6.6%)		
≥ 4	11 (0.4%		
Unknown	82 (2.8%)		

[a]Office for National Statistics 2017: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthsbyparentscharacteristics.
[b]NHS Digital Maternity Services Dataset 2017-2018:https://digital.nhs.uk/data-and-information/data-collections-and-data-sets/data-sets/maternity-services-data-set.

(1.10–1.29). Higher categories of ASA physical status were also associated with a higher incidence of propofol use; OR (95%CI) 1.18 (1.03–1.35). There were variable ORs for propofol usage according to the geographic region in which hospitals were located (Figure 3 and online Supporting Information Table S2).

Short-acting opioids, of which fentanyl was the most popular choice, were given to 1351 (44.2%) patients during induction of general anaesthesia (Table 3; Figure 2). For CS surgery, short-acting opioid use was less common than for non-CS obstetric surgery ($p < 0.001$).

Almost all patients, 3057 (98.1%), received NMB drugs (Table 3). Suxamethonium was used more frequently, 2631 (84.4%), than rocuronium, 367 (11.8%), as the NMB drug for tracheal intubation. Of the 1620 patients that received non-depolarising NMB drugs, 1427 (88.1%) received reversal drugs. In 1184 (83.0%) patients, the drug combination used was neostigmine with glycopyrrolate. Sugammadex reversal was used in 219 of the 533 patients (41.1%) who received rocuronium. Nerve stimulator monitoring of neuromuscular blockade was documented for 855 (52.8%) patients who received non-depolarising NMB drugs.

Processed EEG depth of anaesthesia monitoring was used in 148 (4.7%) patients in only seven hospital sites. No other form of depth of anaesthesia monitoring was recorded.

Tracheal intubation was the airway management method for 3099 (99.4%) patients. A supraglottic airway was used in the remaining 18 (0.6%). A first-generation supraglottic airway was used in 3 patients and second generation in 15 [14]. Of these 18 patients, the supraglottic airway was used in 8 (44.4%) as a rescue device following failed attempts at tracheal intubation. The remaining supraglottic airways were used predominantly in non-emergency, non-CS surgery (including insertion of cervical cerclage and manual removal of placenta). No patients required emergency front of neck access surgery for a 'can't intubate, can't oxygenate' scenario and no cricothyrotomies

Table 2 Urgency and indication for general anaesthesia and surgery for obstetric patients. Multiple indication for general anaesthesia were permissible, hence the total exceeds the number of patients. Values are number (proportion).

Characteristic		CS surgery n = 2554	Non-CS surgery[a] n = 563	Total n = 3117
Urgency of surgery	Emergency/category 1	1329 (52.0%)	307 (54.5%)	1636 (52.5%)
	Urgent/category 2	676 (26.5%)	139 (24.7%)	815 (26.1%)
	Expedited/category 3	159 (6.2%)	19 (0.6%)	178 (5.7%)
	Elective/category 4	375 (14.7%)	12 (3.3%)	387 (12.4%)
	Unknown	15 (0.6%)	86 (15.3%)	101 (3.2%)
Start of GA relative to surgical start	De novo	1708 (66.9%)	494 (87.7%)	2202 (70.6%)
	Conversion from neuraxial anaesthesia to GA after initial surgical incision	809 (31.6%)	52 (9.2%)	861 (27.6%)
	Unknown	37 (1.4%)	17 (3.0%)	54 (1.7%)
Indication for GA	Clinical urgency (e.g. threat to life of mother or neonate)	1279 (50.1%)	345 (61.3%)	1624 (52.1%)
	Maternal preference (e.g. anxiety)	242 (9.5%)	66 (11.7%)	308 (9.9%)
	Neuraxial block contra-indicated (e.g. thrombocytopenia, sepsis)	333 (13.0%)	130 (23.1%)	463 (14.9%)
	Failed neuraxial block (e.g. unable to site neuraxial block, inadequate or early receding sensory block height)	751 (29.4%)	51 (9.1%)	802 (25.7%)
	High neuraxial block (e.g. total spinal or patient distress from high block)	18 (0.7%)	4 (0.7%)	22 (0.7%)
	Other (e.g. prolonged surgery, indicated for surgical procedure)	86 (3.4%)	39 (6.9%)	125 (4.0%)
	Unknown	27 (1.1%)	10 (1.8%)	37 (1.2%)

CS, caesarean section; GA, general anaesthesia
[a]Exploration under anaesthesia = 38.0%; manual removal of placenta (MROP) = 35.8%; Other = 26.2%.

were performed. There were two complications of suspected gastric aspiration during airway management.

Grade 3–4 laryngoscopy occurred in 78 (2.5%) or 1 in 40 general anaesthetics (95%CI 1 in 32–50) of all general anaesthetics (Table 4). A small proportion (1.4%) of airways with a grade 1 view at direct laryngoscopy was subjectively reported as difficult. These were associated with vocal cord oedema in the context of pre-eclampsia or technical problems (including tracheal tube cuff leakage or difficult bag-valve mask ventilation).

Difficult intubations for all types of obstetric surgery were reported in 163 (5.2%) or 1 in 19 (95%CI 1 in 16–22) of all general anaesthetics. For patients with reported difficult tracheal intubation, a bougie was used successfully in 103 (66.9%). Videolaryngoscopy was used rarely, in only 59 (1.9%) patients. Failed intubation occurred in 10 (0.32%) patients or 1 in 312 (95%CI 1 in 169–667). General anaesthesia was continued with a supraglottic airway device for airway management in 9 of these patients. One received general anaesthesia following unsuccessful attempts at neuraxial anaesthesia. The trachea could not be intubated, but the patient was safely woken and a neuraxial block established before surgery was started.

Difficult intubation was reported in 138 (5.4%) patients or 1 in 19 (95%CI 1 in 16–22) for CS surgery, and in 26 patients (4.6%) or 1 in 22 (95%CI 1 in 15–33) for non-CS surgery. Failed intubation occurred in 7 patients (0.27%) or 1 in 370 (95%CI 1 in 179–909) for CS surgery and in 3 patients (0.53%) or 1 in 188 (95%CI 1 in 65–909) for non-CS surgery.

Two patients underwent planned awake tracheal intubation for known difficult airways using flexible bronchoscopy before category 3 and 4 CS surgery. Neuraxial anaesthesia was contraindicated in both patients, who received remifentanil target-controlled infusions for sedation during airway management. Neither had any reported complications.

On regression analysis, the OR of encountering a grade 3–4 laryngoscopy was not significantly related to: weight ($p = 0.41$); BMI ($p = 0.87$); age ($p = 0.13$); grade of anaesthetist ($p = 0.74$); surgical procedure ($p = 0.58$); choice of induction hypnotic drug ($p = 0.29$); choice of NMB drug ($p = 0.22$); urgency of surgery ($p = 0.51$); or whether general anaesthesia was commenced prior to the initial surgical incision or during surgery, as a conversion from regional anaesthesia ($p = 0.66$). Raised BMI was not

Table 3 Summary of selected general anaesthetic and surgical characteristics for all obstetric surgery, caesarean section and non-CS surgical procedures only.

Characteristic		CS surgery n = 2554	Non-CS surgery n = 563	Total n = 3117
Induction hypnotic drug	Thiopental	1431 (56.0%)	218 (38.7%)	1649 (52.9%)
	Propofol	1093 (42.8%)	326 (57.9%)	1419 (45.5%)
	Ketamine	9 (0.4%)	19 (3.4%)	28 (0.9%)
	Unknown	18 (0.7%)	0 (0%)	18 (0.6%)
Neuromuscular blocking drug for tracheal intubation	Suxamethonium	2158 (84.5%)	473 (84.0%)	2631 (84.4%)
	Rocuronium	292 (11.4%)	75 (13.3%)	367 (11.8%)
	Atracurium	50 (2.0%)	9 (1.6%)	59 (1.9%)
	Unknown	54 (2.1%)	6 (1.1%)	60 (1.9%)
Opioid use during GA induction	None	1623 (63.5%)	143 (25.4%)	1766 (56.7%)
	Fentanyl	487 (19.1%)	314 (55.8%)	801 (25.7%)
	Alfentanil	411 (16.1%)	103 (18.3%)	514 (16.5%)
	Remifentanil	33 (1.3%)	3 (0.5%)	36 (1.2%)
Maintenance anaesthetic agent	Sevoflurane	2141 (83.8%)	457 (81.2%)	2598 (83.3%)
	Isoflurane	251 (9.8%)	54 (9.6%)	305 (9.8%)
	Desflurane	80 (3.1%)	17 (3.0%)	97 (3.1%)
	Total intravenous anaesthesia	18 (0.7%)	5 (0.9%)	23 (0.7%)
	Unknown	63 (2.5%)	30 (5.3%)	90 (2.9%)
Nitrous oxide use during GA maintenance	Nitrous oxide	1259 (49.3%)	267 (47.4%)	1526 (49.0%)
Postoperative destination	Delivery suite or post-natal ward (level 0)	1722 (67.4%)	256 (45.4%)	1978 (63.5%)
	Obstetric high dependency care unit (level 1-2)	756 (29.6%)	264 (46.9%)	1020 (32.7%)
	General intensive care unit (level 2-3)	44 (1.7%)	26 (4.6%)	70 (2.2%)
	Unknown	32 (1.3%)	17 (3.0%)	49 (1.6%)
Time of GA induction	20.00–07.59 (i.e. night shift)	1117 (43.7%)	266 (47.3%)	1383 (44.4%)

CS, caesarean section; GA, general anaesthesia

associated with grade 3–4 laryngoscopy, but was associated with difficult intubation; OR 1.09 (1.02–1.17), p = 0.013.

Ten patients (0.3%) had grade 4 views at direct laryngoscopy, two of which resulted in a failed intubation and subsequent rescue with a supraglottic airway device. Videolaryngoscopy was not used for either patient. The trachea was intubated using a bougie in two patients and videolaryngoscopy in six patients.

Over half of general anaesthetics, 1732 patients (55.6%), were started during day shift hours (08.00 to 20.00). With only 446 (14.3%) procedures reported, the least common time period for general anaesthetics to start was 04.00 to 08.00. Weekend days had a mean (95%CI) difference of 27.4% (26.5–28.3 %) fewer general anaesthetics than weekdays.

Staffing for general anaesthetics differed significantly depending upon the general anaesthesia start time, with consultant presence falling from 1067 (64.1%) during the day shift to 145 (11.0%) overnight. Difficult intubation was not reported more frequently during day shift hours compared with overnight; 98 (5.7%) vs. 66 (4.8%), respectively, p = 0.26; nor was grade 3–4 laryngoscopic view; 50 (3.9%) vs. 28 (2.0%), respectively, p = 0.15.

Discussion

The main findings of this study concern changes in the use of anaesthetic agents. The 'traditional' use of thiopental and suxamethonium for RSI in obstetric anaesthesia has been practiced in the UK for longer than in many other countries, but propofol and, to a lesser extent, rocuronium are now being used more frequently. A 2013 UK survey of consultant obstetric anaesthetists identified that thiopental was routinely used by 93% of respondents for induction of general anaesthesia for CS [15], and in the same year NAP5 also found that thiopental was used in 97% of obstetric general anaesthetics. Our finding, that thiopental was used in just over half of patients, with propofol used in most of the

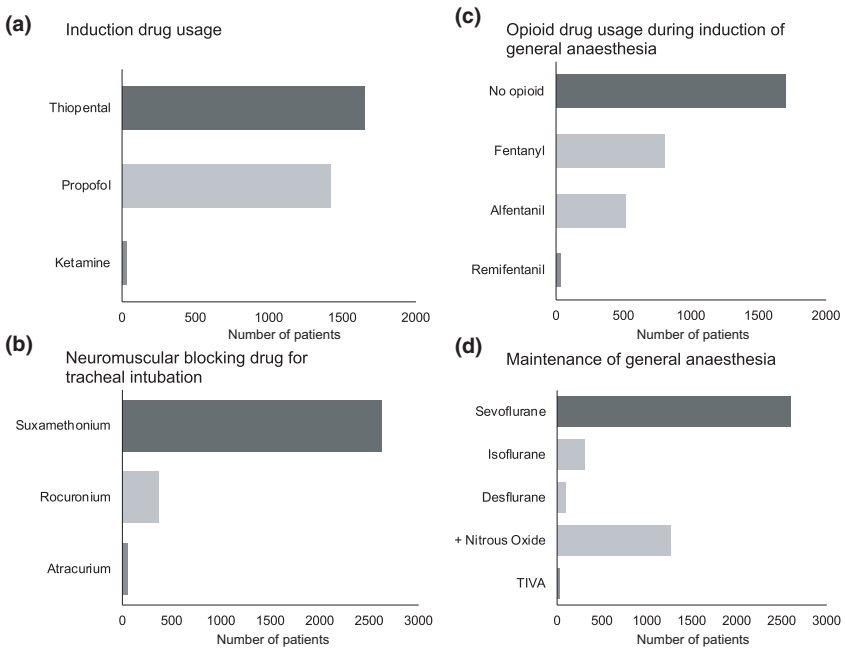

Figure 2 Summary of selected general anaesthetic characteristics. Data are total number of patients. + nitrous oxide data indicates when used in addition to other agents.

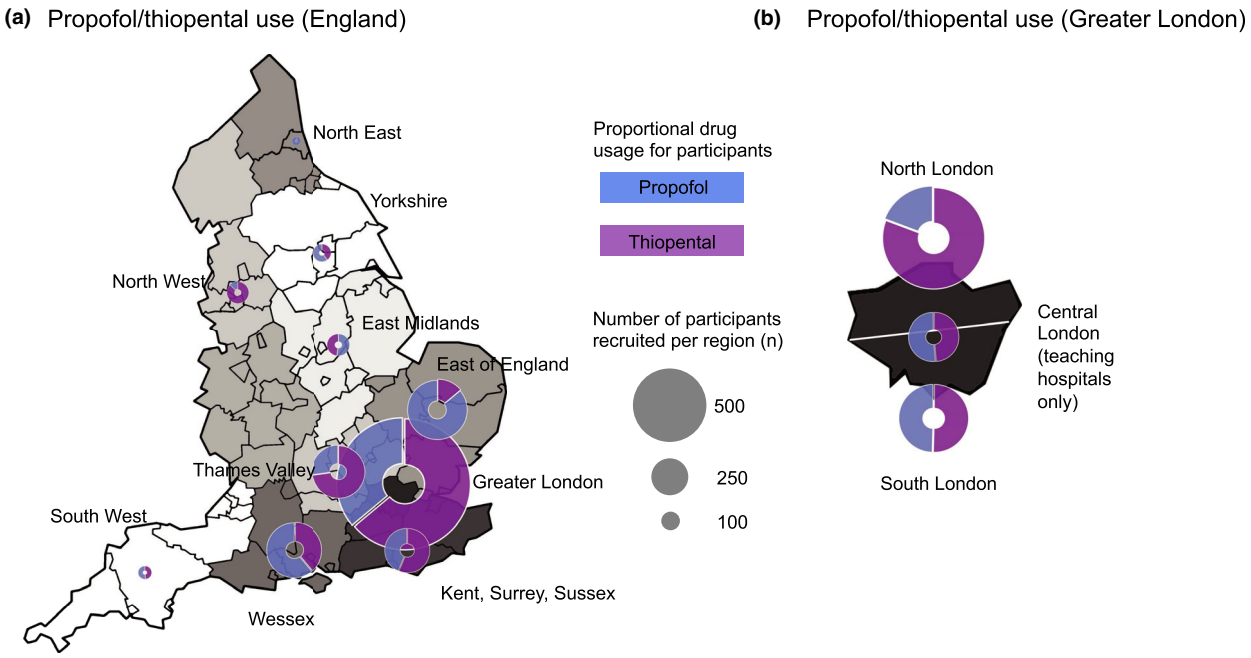

Figure 3 Geographic distribution of induction hypnotic drug use for general anaesthesia according to Health Education England anaesthetic training regions in (a) England and (b) Greater London. Size of each plot represents the proportional number of patients originating within the corresponding region. Since Greater London represented 39.8% of all participating hospitals and 41.9% of all patients the region has been plotted separately.

others, represents a significant change in practice. Propofol use was associated with procedures other than CS, less urgent surgery and patients with more comorbidities; however, the use of thiopental remains extremely high compared with its use within the non-obstetric surgical population (2.9%) [1].

The relative persistence of thiopental as the induction agent of choice in obstetrics was attributed to two main

Table 4 Modified Cormack and Lehane view obtained by direct laryngoscopy and airway outcome. Values are number (proportion).

Grade of direct laryngoscopy	All n = 3117	Difficult intubation n = 163	Failed intubation n = 10
1	2355 (75.6%)	34 (20.9%)	0
2a	382 (12.3%)	29 (17.8%)	0
2b	147 (4.7%)	38 (23.3%)	4 (40%)
3	68 (2.2%)	45 (27.6%)	2 (20%)
4	10 (0.3%)	8 (4.9%)	2 (20%)
Unknown	155 (5.0%)	9[a] (0.6%)	2 (20%)[a]

[a]Videolaryngoscopy only used, hence no direct laryngoscopy grade obtained.

reasons; a belief that the use of thiopental was associated with a reduced risk of AAGA and improved neonatal outcomes, compared with other agents [15]. The evidence supporting these perceptions is, at best, limited, with almost no adequately powered, large scale investigations [16]. Outside of the UK, there has already been a shift towards propofol as the induction agent of choice for CS under general anaesthesia, most likely as a result of limited access to thiopental (as opposed to clear evidence of benefit with propofol). The debate around this subject in the UK was re-ignited by the publication of NAP5 and the UK Maternal Confidential Death Enquiries report (MBRRACE-UK) [17] by Knight et al. The 5th National Audit in the UK reported that AAGA appeared significantly over-represented in patients who received anaesthetic induction with thiopental. Knight at al. found that in some maternal deaths, the dose of thiopental (and much less often, propofol) used for induction of anaesthesia in severely ill women appeared excessive. These results support the assertion that UK anaesthetists are becoming less familiar with the use of thiopental for induction of anaesthesia, and its continued use in obstetric practice may be causing harm. However, this should be considered in the context of a dramatic reduction in the number of women who received general anaesthesia for CS [18]. It is too soon to say whether the problems highlighted by NAP5 and Knight et al. are related specifically to reduced familiarity with thiopental or to reduced familiarity with the use of GA in obstetric practice in general.

The use of short-acting opioids during induction of anaesthesia has increased; 43.2% of patients in our study received fentanyl, alfentanil or remifentanil at induction. NAP5 reported opioid use in only 23.4% of obstetric general anaesthetics in 2013. Opioids have traditionally been avoided as a component of RSI for CS because of concerns about potential adverse effects on the neonate and, in the event of failed intubation and discontinuation of anaesthesia, potentially delaying the return of spontaneous ventilation in the mother. There is a paucity of data to support either of these assertions. Opioids are effective sympatholytic agents. They can also reduce the 'induction agent – maintenance inhalational gap' that has been identified as a specific problem in general anaesthesia for CS, because surgery starts so soon after induction and potentially increases the risk of AAGA. Previous surveys have identified a disparity between opioid use in obstetric vs. non-obstetric RSI, with greater use outside the obstetric setting [19]. A recent meta-analysis has shown that induction opioids (remifentanil and alfentanil, in particular) appear to be safe, with no significant effect on Apgar scores or neonatal airway intervention [20]. Research is needed to define the ideal dose and timing of opioids during general anaesthesia for CS.

Our data suggest a slight decline in the predominance of suxamethonium in obstetric general anaesthesia. In both the NAP5 (2013) and 6th National Audit Project (NAP6) activity surveys (2016), suxamethonium was used for tracheal intubation in > 90% of obstetric patients [1, 21]. In this study, it was used for 86% of patients, almost all for RSI. There are indications of improvements in practice around the use of NMB drugs since NAP5. In our study, drugs for reversal of neuromuscular blockade were used in 88.1% of patients who received a non-depolarising drug, an increase from 68% reversal usage identified in NAP5, but still leaving more than 1 in 10 patients potentially at risk of AAGA on emergence from anaesthesia due to residual neuromuscular blockade. Both NAP5 and the Association of Anaesthetists' guidelines for standards of monitoring during anaesthesia and recovery recommend using quantitative peripheral nerve stimulation monitoring to reduce this risk [22]. Just over half of the patients in this study who received NMB drugs were monitored with a nerve stimulator, compared with only 38% in overall surgical patients in 2013 and 37% in 2016 [1, 21]. Although

suboptimal practice remains a concern, reversal and monitoring of neuromuscular blockade are more consistent with best practice guidelines in obstetric anaesthesia than for overall surgery in the UK. The role of rocuronium in obstetric anaesthetic practice has yet to be clearly defined, which perhaps explains the change in practice in one area of obstetric general anaesthesia (induction agent) but not another (NMB drug) [23].

A striking finding of our study was a very high incidence of difficult intubation at 1 in 19 (95%CI 1 in 16–22). This is higher than previously reported by a prospective study of 1095 obstetric patients in Australia and New Zealand, which reported an incidence of 1 in 30 (95%CI 1 in 22–43) [24]. The incidence of obesity was high in patients receiving general anaesthesia relative to national maternity statistics, and this is a risk-factor for difficult intubation. We found an incidence of failed intubation of 1 in 312 (95%CI 1 in 169–667), similar to the incidence identified in a prospective study in the UK of 1 in 224 (95%CI 1 in 179–281) [4] and a meta-analysis collating data from international studies, which reported an incidence of 1 in 390 (95%CI 1 in 313–500) [25]. Reassuringly, we found minimal adverse events as a result of this, although it is remarkable that failed intubation prevalence has remained so similar over the past 20 years despite advances in airway management guidance and equipment [25]. In 2011, the 4th National Audit Report (NAP4) received just four reports of adverse airway events in obstetrics [26]. It extrapolated an incidence of severe airway problems of 1 in 4348 (95%CI 1 in 1700–16,000).

The data in our study represent the largest set of prospectively collected obstetric airway management data ever reported in the UK. If our estimate of difficult airway incidence of 1 in 19 is correct, the virtual absence of videolaryngoscopy is a concern, as there is mounting evidence for the benefits of this technique in obstetric airway management [27, 28]. In our study, all six patients in whom grade 4 direct laryngoscopic views were obtained and videolaryngoscopy techniques attempted were managed successfully. A UK national survey found that, in contrast to main operating theatres, the availability of videolaryngoscopes in obstetric units was more limited (91% vs. 55%), respectively, and this must be an urgent priority for obstetric anaesthetists [29]. We did not assess the use of high-flow nasal oxygenation in obstetrics. Although there is mixed evidence about the role of high-flow nasal oxygenation in obstetrics, it would be interesting to assess if this technique influences obstetric practice [30, 31].

The primary strength of this study is that it is one of the largest prospective studies of obstetric general anaesthesia conducted and represents a valuable insight into the current UK obstetric practice. However, this secondary study was limited by a requirement for consent in the primary study (Fig. 1). This led to a higher proportion of women who declined to participate, with only data from patients who specifically consented to the AAGA investigation aspect of the study included within this secondary analysis. Had we confined this to an observational study of practice, no consent would have been necessary and we could have legitimately included greater numbers of patient data.

The conduct of general anaesthesia in obstetrics in England has changed since 2013. This is particularly true of the pharmacological preferences for induction of anaesthesia and neuromuscular blockade. Longer-acting NMB drugs were used more often for tracheal intubation in our study than in the NAP5 activity survey. There was also evidence of increased use of neuromuscular reversal drugs and monitoring of NMB drugs, both critical to minimise the risk of residual blockade and AAGA. However, current practice still falls short of the universal use advised by recent guidelines. Difficult intubation was common and the adoption of more advanced airway techniques such as videolaryngoscopy – even perhaps to the point that this becomes the first-line technique for all obstetric general anaesthetics – may further improve safety.

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Supporting Information

Additional supporting information may be found online via the journal website.

Table S1. Hospital recruitment to the DREAMY study.

Table S2. Odds ratios for the effect of factors on the use of propofol as the induction hypnotic drug for obstetric surgical general anaesthesia.

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