How low can you flow?

Although low- and minimal-flow anaesthesia offers many benefits, successful adoption has been hindered by a lack of simple-to-use methods to guide anaesthetists on the efficient usage of volatile gases. This is now set to change following an advancement in gas monitoring software, which measures the actual agent consumption versus uptake.

D-16140-2009

By analysing the data regarding low and minimal flow anaesthesia from the new Software 4 log on his hospital's Dräger Primus machines, Dr Laws, a consultant anaesthetist at the Sunderland Royal Hospital, has been able to help members of his department assess their individual performances, adapt their routines and reduce their consumption of volatile gases by up to 40%. This reduction should have major benefits for patients, in terms of a better breathing circuit and gas conditioning[1], for his hospital, which will have to spend less on anaesthesia agents, and for the environment, since smaller volumes of greenhouse gases will be released.

Despite its considerable benefits, many anaesthetists are confused about how to use circle breathing systems proactively and efficiently for the delivery of volatile anaesthesia in a safe, efficient and cost-effective manner. Dr Laws, who has been the department's audit coordinator for the past ten years, believes that, "The complicated mathematical modelling associated with low-flow anaesthesia articles, which is incomprehensible to the majority of anaesthetists, has not assisted widespread utilisation of appropriate fresh gas flows."

This sentiment points directly to the need for a more meaningful and easily understood measure of efficiency. "The best measure", according to Dr Laws, "would be to capture the degree to which volatile anaesthesia was being wasted during anaesthesia, as it is both the most costly anaesthetic component delivered and a significant contributor to environmental pollution."

Until now, this was easier said than done. However, new functionality within the Software 4 logbook on his hospital's Primus anaesthetic machines means the data needed to determine how efficiently each volatile was being used can now be readily accessed. The latest Software 4 update produces a summary of each anaesthetic delivered, stating the date, time, duration and total carrier gases consumed per case. Importantly, it also now summarises volatile agent consumption (ml liquid) and volatile agent uptake (ml liquid) for each case.

Calculating volatile ratio

Agent consumption refers to the volume of liquid taken from the vaporiser, whereas agent uptake refers to the volume of agent liquid absorbed by the patient. It is, therefore, easy to calculate the volatile ratio (agent consumption : agent uptake). An example is given below:

MT-0657-2008


Logbook

09:35 Standby
09:35 12 Feb. 2011
09:35 duration [h:min]: 0:30
09:35 consumption [L] O_2: 6 Air: 8 N_2O: 0
09:35 agent consumption [ml] (liquid) Sev: 0 Iso: 28 Des: 0 Hal: 0 Enf: 0
09:35 agent uptake [ml] liquid) Sev: 0 Iso: 21 Des: 0 Hal: 0 Enf: 0

In the above example, the volatile ratio is 28 ml consumed : 21 ml patient uptake, or 1.33 : 1.

[1] Baum, J.A. (2007), Low Flow Anesthesia, pp 94-96, Drägerwerk AG Lübeck, Booklet 9097339

Sunderland Royal Hospital

Sunderland Royal Hospital is a 970-bedded acute hospital serving a local community of 330,000 residents in one of the north-east of England's major cities. It offers a full range of clinical specialties and therapies, including A & E, surgical and medical specialties, therapy services, maternity, and paediatric care. To achieve its vision of "Excellence in Health, Putting People First", it aims to put the patient firmly at the centre of all its services.

David Laws received his training in medicine and anaesthesia in the north-east of England. Since 2001, he has worked as a consultant anaesthetist at City Hospitals Sunderland NHS Foundation Trust. He has interests in anaesthesia for the high-risk surgical patient and quality assurance in perioperative care.

UTILISING VOLATILE RATIO

Using this new parameter, Dr Laws can calculate not only the efficiency of volatile anaesthesia by case, but also the average volatile cost per hour. Furthermore, if he linked these figures to each anaesthetist, he could create the opportunity to compare the performance of individuals against preset departmental standards and benchmarks. The figures generated would be extremely powerful since they would be based on a very wide sample-data from the hospital's 21 operating room Primus machines. Having devised a suitable new way of demonstrating the efficiency of volatile anaesthesia, Dr Laws then needed to prove its utility, make the results widely available and introduce the concept of using it as a measure of individual and departmental performance.

Gaining universal acceptance for a new approach that his colleagues were likely to regard as an intrusion into their personal anaesthetic practice was always likely to be problematic. However, as Dr Laws explained, "There was a need to improve our use of sevoflurane quickly as we were threatened with a significant restriction on its availability in order to reduce anaesthetic department drug costs.

So everyone could see that this was an ideal time to introduce a new method that could potentially improve the efficiency of its use."

Audit phase 1

In Step 1, the objective was to move from the old “low-flow” paradigm, which had failed to improve practice for many years, to the new efficiency paradigm– “volatile ratio”.

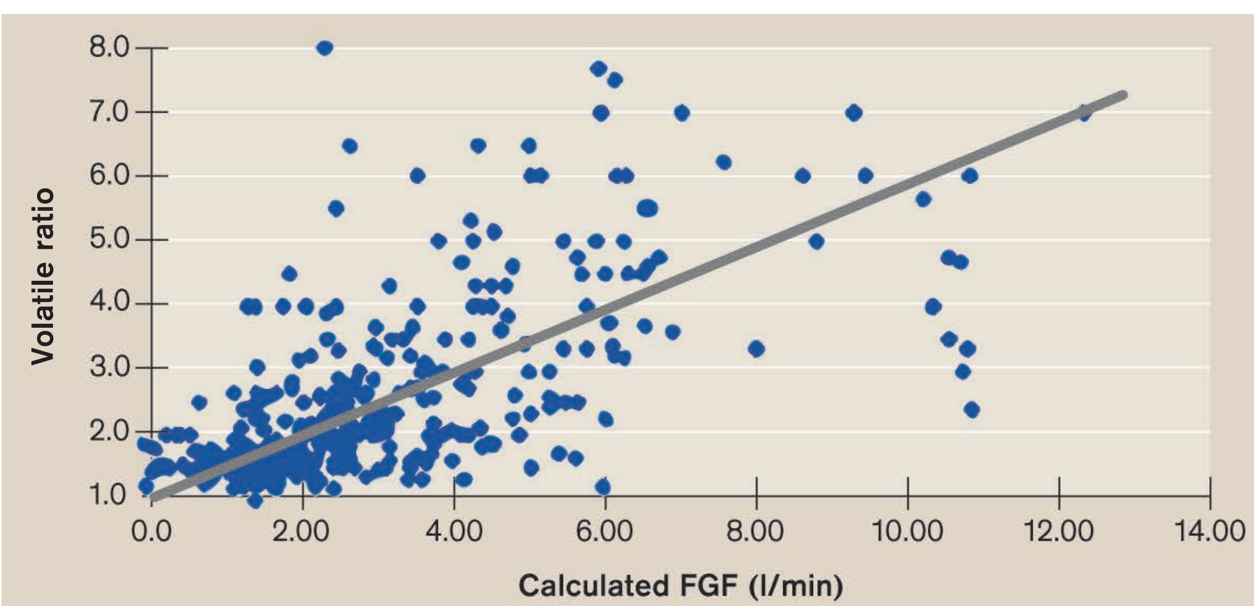
This was achieved by comparing the calculated average fresh gas flow (excluding high-flow oxygen washout at the end of anaesthesia) to the volatile ratio for each anaesthetic via the Dräger Primus anaesthetic machine logbook.

As was expected, the volatile ratio correlated well with fresh gas flows during anaesthesia (correlation coefficient r = 0.63 – Figure 1), demonstrating that higher-maintenance fresh gas flows led to higher volatile ratios (i.e. more waste from utilised volatile).

RESULTS OF PHASE 1

At a departmental meeting, Dr Laws presented the data he had obtained and from it drew the following conclusions:

1) Sevoflurane use was associated with the greatest inefficiency
2) Isoflurane was to become the default volatile agent for all
3) Individual anaesthetic records were to be collected to target inefficiencies
4) Department and individual standard set: 75% of anaesthetics with a duration of less than one hour to have a volatile ratio of less than three
5) Department and individual standard set: 75% of anaesthetics with a duration of more than one hour to have a volatile ratio of less than two
6) Individuals were encouraged to explore the logbook for sel-education



D-7617-2011

Figure 1: Volatile ratio vs fresh gas flow

Audit phase 2

In the next phase, Dr Laws set about feeding back data on individual performance against departmental standards and being able to demonstrate to hospital administrators the increasing use of isoflurane versus sevoflurane within the department.

RESULTS OF PHASE 2

Again, the key was interrogating data stored in the Dräger Primus anaesthetic machine logbook. This showed that a marked reduction in sevoflurane use was achieved with an associated reduction in the average cost per hour of volatile anaesthesia:

	Phase 1	Phase 2
Sevo (% cases)	63.7%	43.5%
Iso (% cases)	34.3%	51.6%
Des (% cases)	1.9%	4.9%
Volatile cost per hour	£6.20	£4.20
Standard violations	42.5%	33.3%
Cases	364	285
Total duration (hours)	422	324

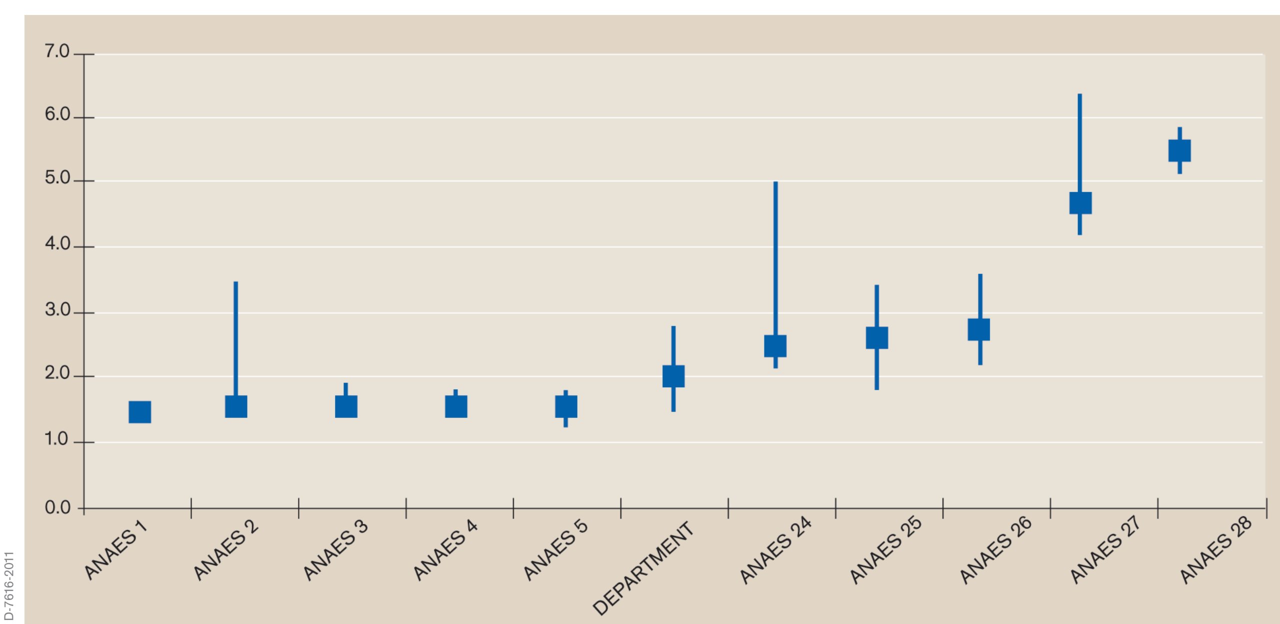


Figure 2: Best and worst performers by volatile ratio median (IQR)

However, it also became apparent that there was great variation in efficiency, as measured by the volatile ratio, between anaesthetists in the department (Figure 2), although some of this could partly be attributed to a differing case mix.

Another positive development was a marginal overall improvement in volatile ratios between phase 1 and 2, as some individuals adjusted their approach to efficiency when they became aware of the significance of the issue (Figure 3).

Crucially, this change in practice led to a 33% reduction in the monthly volatile drug cost!

To help colleagues who were struggling to use circle systems, which was apparent from their own individualised performance data, Dr Laws provided simple instructions listed by volatile agent. This included guidance on setting the desired FiO2, selecting the desired carrier gas, and setting the fresh gas flow (FGF) to equal the minute volume of the patient (see below).

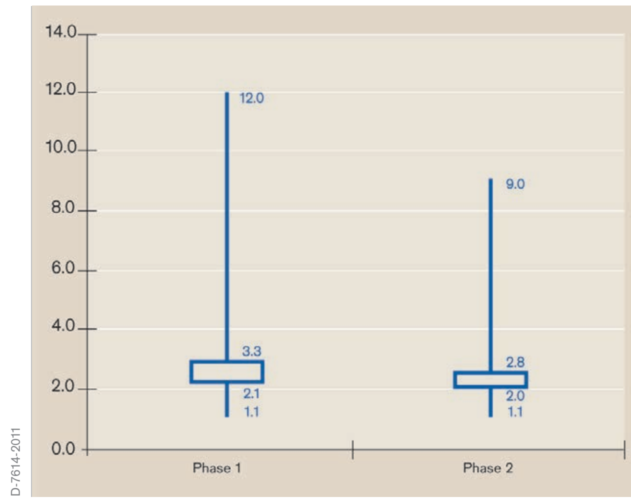


Figure 3: Volatile ratios by month for department (range (IQR))

Sevoflurane:
Set vaporiser to 2.5 times the desired end-tidal agent concentration (typically 5%). Provided minute volume is adequate, when desired end-tidal is reached, reduce FGF to maintenance level (e.g. 0.8 l/min) without vaporiser vapouriser setting initially.

Isoflurane:
Set vaporiser to 2.5–3 times desired end-tidal agent concentration (typically 2.5%). Provided minute volume is adequate, when desired end-tidal is reached, reduce FGF to 2 l/min and then to maintenance level (e.g. 0.8 l/min) a few minutes later without adjusting vaporiser setting initially.

Desflurane:
Set vaporiser to twice the desired end-tidal agent concentration. Provided minute volume is adequate, desired end-tidal is reached very rapidly. Using an initial fresh gas flow of 2 l/min may be preferable given the rapidity of reaching end-tidal targets. Reduce FGF to maintenance level (e.g. 0.8 l/min) on reaching the desired target concentration and subsequently lower the vaporiser setting to maintain the desired concentration.

Audit phase 3

The next elements in the audit process were designed to confirm that any change in volatile use had been continued and to provide individual data for use within annual appraisals.

RESULTS OF PHASE 3

Interrogation of the Dräger Primus anaesthetic machine showed that the departmental reduction in proportional sevoflurane use had, indeed, been maintained, generating an associated sustained reduction in the average cost per hour of volatile anaesthesia (Figure 4).

Interestingly, there was a reduction in the lower-inter-quartile volatile ratio value as a minority of individuals within the department had switched to more efficient practices. Also of note is the increasing use of desflurane, reflecting the expansion of bariatric surgery over the audit period.

	Phase 1	Phase 2	Phase 3
Upper-quartile volatile ratio	3.3	2.8	2.8
Median volatile ratio	2.1	2.1	2
Lower-quartile volatile ratio	2.1	2	1.5
Sevo (% cases)	63.7%	43.5%	44.4%
Iso (% cases)	34.3%	51.6%	48.3%
Des (% cases)	1.9%	4.9%	7.3%
Volatile cost per hour	£6.20	£4.20	£4.30
Standard violations	42.5%	33.3%	31.8%
Cases	364	285	358
Total duration (hours)	422	324	431

Figure 4

Armed with the data from the software log, Dr Laws could now provide permanent members of the department with a summary of their own performance that could be used as part of their annual appraisal.

Audit phase 4

In the most current phase of the audit, Dr Laws wanted to determine whether the enhanced appraisal process had improved departmental and individual performance one year on. (Figure 5).

	Phase 1	Phase 2	Phase 3	Phase 4
Upper-quartile volatile ratio	3.3	2.8	2.8	2
Median volatile ratio	2.1	2.1	2	1.7
Lower-quartile volatile ratio	2.1	2	1.5	1.5
Sevo (% cases)	63.7%	43.5%	44.4%	48.0%
Iso (% cases)	34.3%	51.6%	48.3%	39.9%
Des (% cases)	1.9%	4.9%	7.3%	12.0%
Volatile cost per hour	£6.20	£4.20	£4.30	£4.36
Standard violations	42.5%	33.3%	31.8%	14.2%
Cases	364	285	358	358
Total duration (hours)	422	324	431	448

Figure 5

RESULTS OF PHASE 4

"As Figure 5 indicates, the opportunity to formally reflect on one's prescribing practice as part of the appraisal process, coupled with increased familiarity and acceptance of the methodology used, dramatically improved the departmental performance figures. This was a real step forward, since informal reflection had done very little to improve efficiency."

The overall number of violations fell within the audit standard for the first time.

Although there were 51 violations of the set standards overall (14.2% of cases recorded), the vast majority of the members of the department achieved 100% compliance. Interestingly, five individuals (from a department of 40) accounted for 34 of 51 violations.

Cost per hour was similarly maintained at the lower level (Figure 6), resulting in a confirmed, significant reduction in the volatile drug budget over the previous 12 months (in the order of tens of thousands of pounds).

Figure 6: Volatile ratios by month for department (median (IQR))

DISCUSSION

According to Dr Laws, "Whether anaesthetists employed appropriate flows during anaesthesia was previously regarded as a personal matter and, moreover, one that was best left unexplored. However, when measuring the efficiency of circle breathing system use by monitoring volatile consumption, uptake ratios have proven to be an excellent method of analysing aspects of the performance of the anaesthetic department and individuals within that department.

We have achieved a significant reduction in volatile drug costs with an enhancement in the quality of patient care assisted by the objective data that can be derived from the Dräger Primus anaesthetic machine logbook."

There has also been a major change in attitude. "The majority of anaesthetists within the department are now thinking proactively about priming and maintaining circle systems and use the logbook to reflect upon their efficiency in individual cases."

Audit presentations have also assisted with teaching trainee anaesthetists how to use circle systems appropriately and intelligently, according to the volatile selected.

"As a result of this process, our department has been able to maintain a full complement of volatile agent availability while concurrently achieving significant cost savings," says Dr Laws. "Furthermore, there is no reason why our approach could not be adopted elsewhere in the UK and overseas – with significant benefits for patients, hospitals and the environment."

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