Sir,—We endorse the statement that airway management is the main priority in the care of the unconscious parturient, as indeed it is in all clinical emergencies.

Our patient had a clear airway with effective respiratory function and we believed that the risk of aspiration was small; she remained in a lateral position throughout the episode for the well-being of both herself and the fetus, and she was observed continually by medical personnel skilled in advanced airway management. We did not feel it was necessary to secure and protect the airway with a tracheal tube at any stage; the institution and maintenance of general anaesthesia in an unconscious labouring parturient, and subsequent management of such a patient, would arguably have been more difficult.

There were neither neurological nor autonomic features present to support a diagnosis of raised intracranial pressure in our patient. The rapid onset of the combination of extreme hyperventilation, carpopedal spasm and markedly deranged arterial blood-gas tensions in the presence of more than adequate oxygenation in a previously healthy parturient strongly suggested the diagnosis which was made.

Extradural analgesia was initiated cautiously using divided doses of local anaesthetic solution, in the presence of full monitoring facilities. We would point out that extradural anaesthesia is commonly undertaken safely in patients who are already under general anaesthesia as part of a combined anaesthetic technique. Eliciting parasthesiae is not a prerequisite for performing extradural block.

We reported the successful outcome of a management plan undertaken in a patient with a clinically challenging problem which is seldom seen. Physicians should be aware that hyperventilation may be sufficiently severe to cause unconsciousness during labour; this was our message.

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Nitric oxide delivery system

Sir,—We read with interest Dr Young’s article on a universal nitric oxide delivery system [1]. Our attention was drawn especially to the statement on the use of nitric oxide administered via a Siemens Servo ventilator to the effect that “there is a long residence time for nitric oxide in the system, which encourages the formation of nitrogen dioxide”.

We should like to allay fears on this issue. We have been administering nitric oxide to patients with severe adult respiratory distress syndrome for approximately 18 months. Our apparatus involves introducing oxygen in air (generally 100% oxygen) and nitric oxide in nitrogen to the low pressure inlet of a Siemens Servo 900C ventilator. We monitor both nitric oxide continuously and nitrogen dioxide intermittently downstream from the ventilator using a Micro Gas electrochemical analyser (Micromedical, Rochester, Kent, UK) in addition to measuring methaemoglobin using a co-oximeter at least four times per day.

Having carried out a dose-response study on our first 10 patients, we have established that in this clinical group, further benefit in terms of improvement in the $P_{aO_2}/P_{aCO_2}$ ratio is unlikely at doses greater than 20 parts per million (ppm), and indeed that 10 ppm is generally the appropriate dose. Hence, our policy is to use 10 ppm in most situations, and never to exceed 20 ppm of nitric oxide. Using our system and this dose regimen, we are satisfied that potentially dangerous levels of nitrogen dioxide are not reached even when we have never found an unmeasured concentration greater than 0.6 ppm or a methaemoglobin concentration greater than 0.7%. The inhaled nitrogen dioxide concentration is within recommended acute exposure limits, which are 3 ppm time-weighted average over 8 h with a maximum concentration of 5 ppm over a 10-min period [2].

The reaction rate of nitric oxide with oxygen to give nitrogen dioxide proceeds according to the equation $2NO + O_2 \rightarrow 2NO_2$. The rate of reaction $k$ at $25\, ^\circ C$ is $14.5\, \text{atm}^{-1}\cdot\text{min}^{-1}$. If 20 ppm ($2 \times 10^{-8}\, \text{atm}$) of nitric oxide reacts with 98.5% oxygen, nitrogen dioxide is produced at a rate $5.5 \times 10^{-9}\, \text{atm}^{-1}\cdot\text{min}^{-1}$, that is $5.5\, \text{ppb}\cdot\text{min}^{-1}$.

The maximum acceptable level of nitric dioxide 3 ppm would be reached after 9 min of mixing. This calculation is in general agreement with that made by Foubert and colleagues who suggested that a mixture of nitric oxide 20 ppm in 100% oxygen would take 12 min to produce a concentration of 5 ppm of nitrogen dioxide [3].

Clearly, even with our system, introducing nitric oxide upstream from the Servo ventilator, the mixing time is considerably less; we have measured steady state concentrations of nitric oxide at the tracheal tube 130 s after turning on the supply. We are in agreement with Dr Young that administration of nitric oxide should be monitored closely, especially with respect to generation of nitrogen dioxide. Nevertheless, we would reassure your readers that administration via the low pressure inlet of the Servo ventilator represents an acceptable route of delivery, with no evidence of dangerous levels of nitrogen dioxide resulting when nitric oxide is given in clinically applicable doses of 10–20 ppm.

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Sir,—The article on a universal nitric oxide delivery system [1] hopefully encourages the anaesthesia community to use accurate nitric oxide delivery systems rather than simple but intrinsically unsafe systems. However, the “universal” and “fail safe” delivery device, as described by Young, may not be as precise as desired and, in our opinion, deserves additional refinements, including a risk analysis according to prEN 1441 [2] in order to classify it as a true fail safe system, at least in the light of requirements as laid down in IEC-60601 Part 1 and EN 540 [3].

As we see it, this imprecision is caused by the following: mass flow controllers (MFC) as available from stock are rather slow responding devices (10–90% step response > 100 ms) and therefore fail to follow a fast changing set-point signal. This also becomes evident when comparing the results in Young’s test series with the square and ramp flow patterns. An even more important point to be observed is the limited dynamic (typically 1:100) flow range in which an MFC is working correctly. In a system with flow proportional nitric oxide administration, a much higher dynamic range has to be covered. The ratio between the lowest and highest nitric oxide flow is given by the following equation:

$$\text{dynamic range} = \frac{(\text{maximum inspiratory flow/minimum inspiratory flow})^*}{(\text{minimal adjustable} P_{f100}/\text{minimal adjustable} P_{f100})}$$

An inspiratory flow range of 5–120 litre min$^{-1}$ (e.g., a decelerating flow during pressure controlled ventilation (PCV)) and nitric oxide concentrations adjustable between 1 and 40 ppm result in a dynamic flow range of 960 for the metering device. Therefore, in order to fully meet the clinical requirements both in terms of flow and concentration range, MFC with different ranges (at least 2, e.g. 0–200 ml min$^{-1}$ and 0–2 litre min$^{-1}$) have to be used with the arrangement described (as an alternative, cylinders with different nitric oxide concentrations could be used to cover the full range). We agree with Young’s proposal that an MFC of lower range should allow much better control in the low nitric oxide concentration range; however, in various European countries only “non-toxic” nitric oxide concentrations of less than 1000 ppm [4] are available (in contrast with 2000 ppm as suggested by Young), thus again necessitating a higher flow range for the MFC.

There is another drawback in his design which deserves additional comment. The compressible gas volume between the site of nitric oxide flow measurement (inside the MFC) and the nitric oxide entrance to the breathing circuit decreases the mixing quality of the nitric oxide delivered to the patient. This reduces the generation of nitrogen dioxide, thus allowing a higher flow range for the MFC.

We should like to allay fears on this issue. We have been in agreement with Dr Young that administration of nitric oxide at the tracheal tube 130 s after turning on the supply. We are in agreement with Dr Young that administration of nitric oxide should be monitored closely, especially with respect to generation of nitrogen dioxide. Nevertheless, we would reassure your readers that administration via the low pressure inlet of the Servo ventilator represents an acceptable route of delivery, with no evidence of dangerous levels of nitrogen dioxide resulting when nitric oxide is given in clinically applicable doses of 10–20 ppm.
During early expiration the sudden airway pressure release causes the nitric oxide captured in the delivery line to empty into the Y-piece and subsequently to be washed out by the expiratory flow. Both effects reduce the amount of nitric oxide delivered to the lungs. These losses are more pronounced in patients with low lung compliance receiving low doses of nitric oxide.

As most of the aforementioned characteristics are specific to the chosen site of nitric oxide administration, we suggest that nitric oxide should be added to the breathing gas as close to the inspiratory outlet of the ventilator as possible. In this way, the volume of the entire inspiratory limb, including the humidifier, can be used as a mixing chamber. This single measure reduces the requirement both for the high dynamic range and the fast response of the MFC. It guarantees a uniform nitric oxide concentration during the entire inspiration and avoids inaccuracies in nitric oxide measurement arising from incomplete gas mixing as is to be expected when nitric oxide is delivered close to the gas sampling location. However, one must observe that this modification increases the contact time for oxygen and nitric oxide and thus might contribute to a higher conversion of nitric oxide into nitrogen dioxide, but nitrogen dioxide should always be monitored whenever nitric oxide is administered to a patient [4].

In general, any system, when used for administration of a potent drug, must remain safe and must not harm the patient in the event of even a single fault. As Young pointed out, in the case of a power loss, nitric oxide delivery from the MFC is promptly shut down. However, a nitric oxide "responding" patient may experience a dangerous increase in pulmonary artery pressure or a deterioration in oxygenation caused by sudden withdrawal of the drug, or both [4]. On the other hand, if the mass flow unit fails, nitric oxide delivery cannot be controlled and might exceed the upper range of the MFC. This event might be accompanied by exceedingly high nitric oxide concentrations. In our opinion, the patient must be protected irrespective of any of these conditions by an independent safety valve. Young correctly stated that for clinical use a nitric oxide monitor would be mandatory. At present, however, there is no nitric oxide monitor available which would respond fast enough to measure the nitric oxide concentration on a breath-to-breath basis ("fast" chemiluminescence nitric oxide monitors sample at least 500 ml/min), thus affecting that inspiratory flow (and thereby inspired nitric oxide concentration during the entire inspiration of continuous flow systems we have used up until now). It does, however, represent the first step in the development of an automated system, and not the final solution.

Events, incidents and critical incidents

Sir,—The commentary by Banks and Tackley [1] of the Anaesthetic Specialty Working Group (SWG) on a standard set of terms for critical incident recording does not address a fundamental weakness in the terminology. The use of the term "critical incident" implies that there are some incidents which are not critical. It follows that an incident will progress to become a "critical incident" at some time. At what stage the point of criticality is reached is left to the interpretation of each individual anaesthetist. If the incident was detected and corrected immediately it could be argued that the point of criticality was not reached. But the proposed definition by the SWG of a critical incident is "an event which does not necessarily lead to an undesirable outcome, but which could or would lead to progress". It would simplify matters if the adjective "critical" is not used when describing incidents. There can be an alerting event and a perceived cause for the alerting event. Uniformity in recording can be achieved if consensus can be reached that the perceived cause for the alerting event is the incident.

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Sir,—Drs Gilly and Baum have clearly highlighted some of the problems using mass flow controllers for nitric oxide delivery in a critical care setting. The prototype device I constructed could undoubtedly be improved using a faster mass flow controller with a wider dynamic range, or possibly by carefully adjusting the damping on the mass flow controller feedback loop. Intermittent compression and release of nitric oxide mixtures from the delivery line was not a problem I had considered when constructing the original device. In addition to the suggested solution, other approaches would be to place a check valve in the delivery line close to the point at which it enters the inspiratory limb, or to mount the mass flow controller remotely from the rest of the device, close to the circuit.

Abrupt cessation of nitric oxide treatment can cause a serious rebound increase in pulmonary vascular resistance. This may occur if power is lost to the device. Our current solution is to have a second nitric oxide system available for such an emergency but a fixed-flow bypass valve that opens automatically on power loss may be more appropriate. This gives a variable inspired concentration of nitric oxide depending on the minute ventilation, but if the bypass flow is chosen appropriately, a safe level could be delivered which would prevent abrupt cessation of treatment. An additional point to be borne in mind is that if the patient is removed from the ventilator circuit and the lungs ventilated by another means, for instance a manual ventilating circuit, some method has to be available to deliver the nitric oxide to the second circuit.

Sir,—Thank you for the opportunity to reply to Dr Jayasuriya's letter. We agree that the use of the term "critical incident" poses problems. We headed our list of terms "notable or unfortunate events in patient care" because a critical incident is so difficult to define. Thus an event can be labelled as being "critical" depending on the view of the anaesthetist concerned.

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