in early skill acquisition[2,3] although there is some evidence that high-fidelity models may have an advantage later in the learning curve supporting a graduated approach through models of increasing fidelity.[4] However, we would like to suggest an alternative factor that affects the analysis of Chandra's findings. In addition to differences in fidelity, the models used can also be differentiated according to the part task training theory.[5]

Part task training is defined as the deconstruction of multicomponent tasks into several single-component tasks. When each skill is learned separately, the single-task format allows a more rapid development of automaticity, reducing processing demands during subsequent integration into the performance of the whole procedure.[6] Fiberoptic orotracheal intubation is a complex psychomotor task which requires the association of two component skills: The manipulation of the fiberoptic bronchoscope and the appreciation of the endoscopic view of the upper airway anatomy.

The AccuTouch Flexible Bronchoscopy Simulator (Immersion Medical, Gaithersburg, MD) can be considered a full task trainer model, whereas the "choose-the-hole" model can be classified as a single task trainer dedicated to learn specifically the manipulation of the bronchoscope. The other component skill of identifying the endoscopic appearance of the airway anatomy can be achieved through other simulators such as the virtual fiberoptic intubation part task trainer. The virtual fiberoptic intubation software (Institut de Recherche contre les Cancers de l'Appareil Digestif, Strasbourg, France) is a free screen-based simulator that focuses on learning normal and altered endoscopic airway anatomy away from the fiberoptic bronchoscope.[7] Using only the computer's mouse or keyboard, this virtual progression helps the learner to mentally integrate the schema of the correct airway route. The difference between the groups in Chandra's study is not only one of fidelity, but also the difference between a full-task and a part-task simulation. It is interesting that there was no difference between the groups, and we can only speculate whether there would have been a difference if the part-task group had in addition used another part-task trainer such as the virtual fiberoptic intubation part task trainer to enable deliberate practice of both component skills.

We suspect that each type of simulator has a specific role. Part task trainers may be used for learning each component of a complex task, whereas full task trainers may be used to integrate those skills before working in the clinical setting. Given that Chandra *et al.* found a single part task trainer to be equivalent to a full task trainer, we hypothesize that the use of complementary single task trainers has the potential to be more effective than a full task trainer in early skill acquisition for fiberoptic orotracheal intubation.

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A Near Miss: A Nitrous Oxide-Carbon Dioxide Mix-up Despite Current Safety Standards

To the Editor:—This case summary reports the inadvertent connection of a nitrous oxide hose to a carbon dioxide wall outlet and subsequent administration of high levels of carbon dioxide gas to a patient during anesthesia. The possibility of such a misconnection was unexpected, as it was assumed that the safety-keyed connection system would not allow such a coupling. Therefore, we consider it important to warn others of this occurrence.

Briefly, a healthy 32-y-old male presented for extracorporeal shockwave lithotripsy. The case was scheduled in a "procedure room." Because of the small size of this room there is no boom dedicated to the delivery of anesthesia gas and electricity, as there is in the standard operating rooms. Medical gas hoses from the Draeger Narkomed 2B anesthesia machine (Draeger Medical, Inc., Telford, PA) have to be connected to gas outlets on the wall. This is the only operating room at our institution with such a configuration. The gas outlets (Connect2 Quick-Connect Medical Gas Outlets) and hose connectors (Ohmeda-style male hose adapters) were manufactured by Allied Healthcare Products, Inc., St. Louis, MO.

On the morning of surgery, a CA-1 anesthesia resident performed the daily equipment check but did not check the nitrous oxide line up to the wall outlet. After premedication the patient was transported to the operating room. He received 100 mg of lidocaine with 30 mg of propofol after preoxygenation. Nitrous oxide and oxygen flows were turned to 4 l each, and an inhalational induction was planned with sevoflurane. The patient continued breathing for 2 to 3 min without any change in consciousness; the induction was taking longer than anticipated. Upon checking the anesthesia machine, it was noticed that there was no nitrous oxide gas flow and the nitrous oxide hose was disconnected from the wall. The lithotripsy machine technician was standing nearby and was asked to attach the nitrous oxide hose to the wall outlet. After connection, the pipeline pressure gauge rose and there was return of flow through the nitrous oxide flow meter. Soon, the patient started to noisily hyperventilate, exchanging very large tidal volumes (> 1,000 ml). The capnograph audibly alarmed, showing an end-tidal carbon dioxide of 105 mmHg. The gas supply source was checked, and it was found that the nitrous oxide gas line was connected to the carbon dioxide gas wall outlet. As this particular room had no nitrous oxide wall outlets, the nitrous oxide hose was disconnected from the carbon dioxide wall outlet to allow use of the E cylinder of nitrous oxide (otherwise, the pressure differential would favor the higher-pressure wall source). The E cylinder was then employed for induction and maintenance of the patient. After the patient was

Support was provided solely from institutional and/or departmental sources.

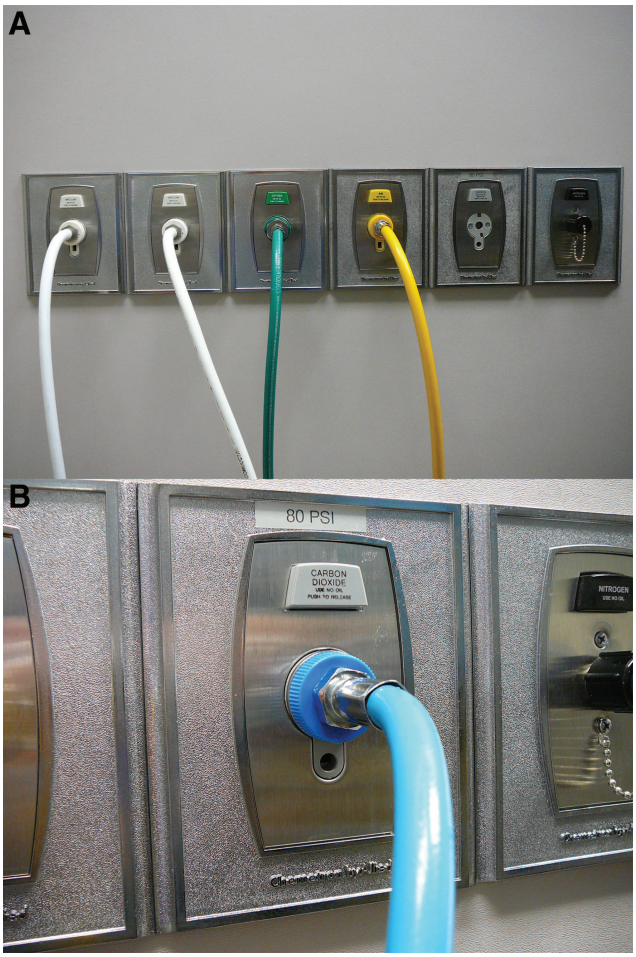

Fig. 1. (*A*) Chemetron Connect2 Quick-Connect Medical Gas Outlets (Allied Health Products, Inc., St. Louis, MO). From left to right: Vacuum, vacuum, oxygen, air, carbon dioxide, nitrogen. (*B*) The nitrous oxide gas line (blue) with an Ohmeda-style male hose adapter (Allied Health Products, Inc., St. Louis, MO) firmly inserted into the carbon dioxide gas outlet.

adequately anesthetized, a laryngeal mask airway was inserted. The patient was hemodynamically stable throughout. The procedure was completed and the patient woke up without any complications or delay.

A number of safety failures made this error possible. First, during the initial check of the machine, the anesthesia provider did not recognize that there was no nitrous oxide supply to the machine because of the lack of a wall outlet in the room and because the nitrous oxide cylinder was off. Second, the person who was asked to make the connection was untrained in handling anesthesia equipment and ignored the wall plate labeling and color-coding system* (fig. 1A).

Third, there was a failure of the gas exclusivity safety system. It was possible to easily connect a male nitrous oxide hose adapter to a female carbon dioxide wall outlet. The discovery of such a design error is of great concern and relevant to all anesthesia providers. It is imperative that everyone who handles such equipment know that if the Ohmeda-style nitrous oxide male hose adapter is rotated 180 degrees from its normal orientation, it is easily inserted and latched into the carbon dioxide wall outlet (fig. 1B).

The Connect2 Quick-Connect Medical Gas Outlets, unlike the pipeline systems, are not regulated by national standards, but are manufac-

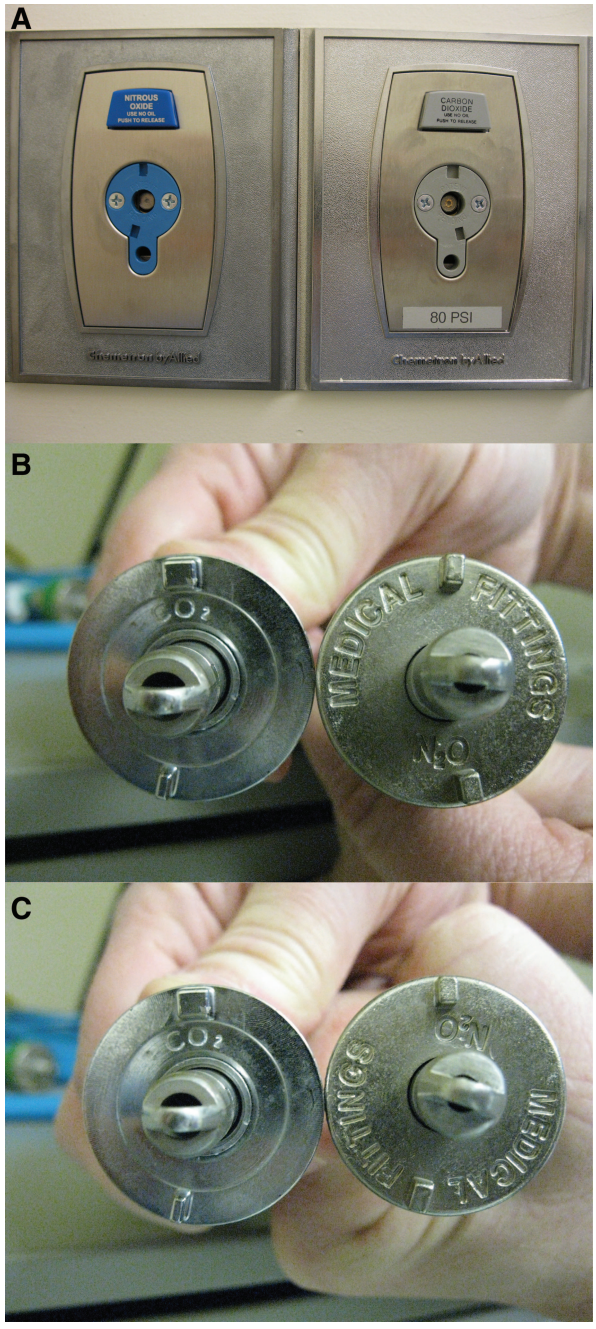

Fig. 2. (*A*) Close view of the Chemetron Connect2 Quick-Connect Medical Gas Outlets (Allied Health Products, Inc., St. Louis, MO). This picture was taken at the Simulation Center and not in an operating room. Note the orientation of the slots. Measurements for the nitrous oxide slots at both positions are 3.302 by 5.334 mm (width by height). Measurements for the carbon dioxide slot at the 12 o'clock position are 5.080 by 5.334 mm. At five o'clock, the measurements are 3.302 by 5.080 mm. The diameter of the central hole is 9.906 mm for both outlets. (*B*) Close view of the Ohmeda-style male hose adapters (Allied Health Products, Inc., St. Louis, MO) for nitrous oxide (right) and carbon dioxide (left). Measurements for the nitrous oxide pins are 3.048 by 3.810 mm for both. The pins for the carbon dioxide adapter measure 4.572 by 4.064 mm at twelve o' clock and 4.064 by 2.286 mm at seven o'clock. The diameter of the central pin is 9.398 mm for both. (*C*) Rotation of nitrous oxide male hose adapter by 180 degrees. With rotation of the nitrous oxide male hose adapter the pins easily fit into the carbon dioxide gas outlet slots.

* Joint Commission. "Medical Gas Mix-ups." Sentinel Event Alert. Issue 21–July 1, 2001. http://www.jointcommission.org/SentinelEventsAlert/sea_21.htm. Accessed November 14, 2008.

Fig. 3. The Narkomed 2B anesthesia machine medical gas pipeline gauges (Draeger Medical, Inc. Telford, PA) with the nitrous oxide line connected to the carbon dioxide wall gas outlet. Note that the nitrous oxide gauge is reading 62 psig, which is higher than one would expect if the line were connected correctly to the nitrous oxide wall outlet.

turer-specific.[1] We, as well as the manufacturer, had falsely assumed that medical gas connections have uniquely oriented and sized pins and slots so that it would be impossible to misconnect gases (fig. 2, A–C). The manufacturer has redesigned the carbon dioxide wall plate so that such an interconnection is impossible.

The importance of a properly conducted machine check cannot be overemphasized. The resident performing this important step likely missed a zero reading on the nitrous oxide pipeline pressure gauge. Interestingly, the residual nitrous oxide left in the circuit of the machine from a previous E cylinder use resulted in an adequate cylinder pressure reading and allowed the resident to set a flow of nitrous oxide at 4 l/min for several seconds. This initial flow reassured the resident that the system was operational, but of course, the nitrous oxide flow quickly diminished as the induction ensued.

The resident does not remember having checked the nitrous oxide pipeline pressure at the anesthesia machine gauges, and this missed check was one of the root causes of this event. In fact, the 2008 American Society of Anesthesiology checkout procedures state that one should "verify that piped gas pressures are greater than or equal to 50 psig."† Interestingly, if the nitrous oxide had already been connected to the carbon dioxide, the nitrous oxide pipeline pressure would read a pressure value greater than 50 psig because carbon dioxide pressures in our hospital's central supply are 70–80 psig, corresponding to a pressure of 60–70 psig on the Narkomed nitrous oxide gauge (fig. 3). This is important, as the Checkout Recommendations of 1993 indicate one should "check that hoses are connected and pipeline gauges read about 50 psig."‡ Perhaps the 2008 recommendations should include checking the hose/outlet connections, and also ensuring a safe range of pressure from the central source and not just a reading greater or equal to 50 psig.

In searching the literature, we found a previous report of such a gas mix-up that was published in 1993.[2] In that case, the failure of the indexing system resulted from a technician who had intentionally enlarged the slot on the female carbon dioxide outlet because the carbon dioxide connector kept disengaging. The manufacturer of those pieces of equipment was Ohio Medical Products, currently Ohio Medical, Gurnee, Illinois.

After this event occurred at our institution, we took the following steps to disseminate this safety information: 1) The "procedure room" was closed pending the replacement of the carbon dioxide quick connectors and outlets. 2) An e-mail alert was sent to all operating room staff. 3) The Food and Drug Administration was informed through a Medwatch report; the Anesthesia Patient Safety Foundation and the Emergency Care Research Institute were also informed. 4) The manufacturer has been contacted, and they have redesigned their gas outlet connector system. 5) The case was presented at our Anesthesiology Department Morbidity and Mortality Conference. 6) Our hospital is currently replacing all nitrous oxide connectors with the ones produced by Bay Corporation, Westlake, Ohio, to make sure that nitrous oxide and carbon dioxide outlets and hoses are uniquely key-indexed.

In conclusion, this is a medical gas delivery error that has brought to light a flaw in the safety key system of the medical gas wall outlet connection system. In addition, we show that gas gauge pressures above 60 psig should be regarded as a sign that there is a gas line misconnection. We also hope that our experience may prompt quick industry-wide action to prevent a repeat of this hazardous occurrence.

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† Recommendations for Pre-Anesthesia Checkout Procedures (2008) Sub-Committee of ASA Committee on Equipment and Facilities. http://www.asahq.org/clinical/finalcheckoutdesignguidelines02.08-2008.pdf. Posted March 13, 2008. Accessed February 4, 2009.

‡ Anesthesia Apparatus Checkout Recommendations, (1993) http://www.osha.gov/dts/osta/anestheticgases/index.html#Appendix2. Posted May 18, 2000. Accessed February 4, 2009.