

**Supporting information for  
Patient Safety Alert:**

**Reducing the risk of  
connecting oxygen  
tubing to air flowmeters**

**4 October 2016**

## About NHS Improvement

NHS Improvement is responsible for overseeing foundation trusts, NHS trusts and independent providers. We offer the support these providers need to give patients consistently safe, high quality, compassionate care within local health systems that are financially sustainable. By holding providers to account and, where necessary, intervening, we help the NHS to meet its short-term challenges and secure its future.

NHS Improvement is the operational name for the organisation that brings together Monitor, NHS Trust Development Authority, Patient Safety, the National Reporting and Learning System, the Advancing Change team and the Intensive Support Teams.

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## Introduction

NHS Improvement issued a [Patient Safety Alert on 4 October 2016](#) to reduce the risk of connecting oxygen tubing to air flowmeters. This supporting information provides context for the alert and further details on our review of incidents and recommended actions.

## Previous Patient Safety Alert on oxygen safety in hospitals

Incidents leading to death and severe harm have been reported to the National Reporting and Learning System (NRLS) that describe the inadvertent connection of tubing to medical air instead of the oxygen supply intended for the patient's treatment. A Rapid Response Report<sup>1</sup> (RRR) issued by the National Patient Safety Agency (NPSA) in 2009 highlighted this risk and made recommendations to prevent such incidents. All hospitals providing NHS-funded care were asked to assess the risks of confusing oxygen and medical air and to develop action plans. The following solutions were suggested:

- removing air flowmeters from the outlets when these are not in active use; removing unnecessary equipment is a more effective method of reducing human error than displaying warnings on that equipment
- placing warning labels on air and oxygen wall outlets
- colour coding flowmeters (white – oxygen; black – air)
- putting covers on air flowmeters that are used intermittently
- ensuring that flowmeters are not obscured by curtains or other equipment
- restricting the use of compressed air outlets on general wards (given the increased use of electrically driven compressors to provide an air supply for nebulisers).

## International work to prevent misconnections

The RRR (NPSA, 2009) stated that in the longer term, a design-led solution would be helpful to make it impossible to connect standard oxygen tubing to an air outlet. International connector standards are being developed for breathing systems and driving gases applications (ISO 80369, Part: 2). However, it is unclear at the moment whether these new connectors will differentiate between oxygen and medical air. In addition, publication of ISO 80369-2 has been delayed, and even when published, it could take industry many years to adopt the new connector design.

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<sup>1</sup> NPSA (2009) *Oxygen safety in hospitals* <http://www.nrls.npsa.nhs.uk/alerts/?entryid45=62811>

## Confusion between oxygen and air flowmeters

Flowmeters are used to deliver accurate flow rates of medical gases to a patient; as the control knob on the front of the unit is turned, a ball or bobbin inside the tube rises and falls to indicate the rate at which gas is being delivered.

Oxygen and air flowmeter probes are gas specific and can only be connected to a wall outlet of the same type, so for example an oxygen flowmeter can only be connected to an oxygen terminal unit (wall outlet). However, oxygen and air flowmeters are often mounted side by side and once connected to the terminal unit (wall outlet), they look very similar. In addition, the flowmeter outlets (of a “Christmas tree” shape) are identical and flexible ‘balloon’ tubing to convey medical gases can be attached to both.

Most suppliers colour code the flowmeter bodies (white for oxygen and black for air) and standards require labelling of flowmeters. However, the size of the lettering is limited by the dimensions of the meters and so may not have sufficient impact.

**Figure 1: Oxygen flowmeters (left) are usually white and medical air flowmeters (right) are usually black**



Source: Colchester Hospital University NHS Foundation Trust training material

## Medical gas pipeline systems

Medical gas pipeline systems (MGPS) supply oxygen and medical air to where it is needed to various parts of the building. Equipment is connected to the MGPS system via wall outlets. Medical gas outlets are designed to be gas specific and can only be connected to a probe of the same type. Detailed information about these systems can be found in the [Health Technical Memorandum 02-01 \(DH Estates and Facilities Division, 2006\)](#).

## Oxygen

Oxygen is vital to sustain life. It is one of the most commonly used medicines in hospital environments and part of first-line treatment in many critical conditions. Further information about safe oxygen administration can be found on the British Thoracic Society website: [www.brit-thoracic.org.uk/standards-of-care/guidelines/bts-guideline-for-emergency-oxygen-use-in-adult-patients/](http://www.brit-thoracic.org.uk/standards-of-care/guidelines/bts-guideline-for-emergency-oxygen-use-in-adult-patients/)

## Medical air

Like atmospheric air, medical air contains 21% oxygen. Its main uses in hospitals are:

- **Driving nebulisers.** A nebuliser is a device that converts medication solutions into aerosols suitable for inhalation. Nebulisers are widely used in the treatment of respiratory diseases, eg asthma, chronic obstructive pulmonary disease (COPD) and cystic fibrosis. While piped medical air can be used to nebulise medication, machines that compress atmospheric air are widely available and some sites use ultrasonic nebulisers. Therefore, piped medical air has become obsolete in some areas that use these alternatives.
- **Driving ventilators and resuscitaires.** Patients sensitive to oxygen toxicity are given air to lower their exposure to oxygen, eg neonates, patients with chronic hypoxaemia (as in severe COPD) and those with acute pulmonary problems with severe hypoxia.
- **Power source for driving surgical tools.** These tools require high flow and high pressure air ('surgical air'). These power sources cannot be mistaken for oxygen outlets as they have different connections.
- **Carrier gas for volatile anaesthetic agents** in anaesthesia.

The above list shows that, unlike oxygen, flowmeters for medical air are never required in an emergency. Therefore, withdrawing 'immediate' access to medical air would not introduce risks to patients. Of course, any actions plans to do this would need to ensure alternative arrangements are in place to meet patient needs (eg increased stocks of compression or ultrasonic nebulisers).

## Review of reported incidents

We searched the NRLS on 15 June 2016 for incidents reported since 1 January 2013 that contain the keywords 'air' and 'oxygen' in their free text descriptions. This search strategy identified 5,943 reports. A sample of 593 incidents was reviewed. This included:

- all incidents reported as resulting in severe harm or death (n = 120)
- all incidents reported as resulting in 'moderate harm' for which the incident type was reported as medication, medical device, treatment or implementation of care (n = 285)
- all incidents reported as resulting in 'low harm' for which the incident type was reported as medication or medical device (n = 188).

In addition, all remaining incidents were searched for the keywords ‘instead’ or ‘flowmeter’ (using the ‘Excel find function’).

In total, 208 incidents were identified where oxygen tubing had inadvertently been connected to a medical air flowmeter. Most incidents were reported as resulting in no or low harm to the patient but there were four reports of severe harm and death (Table 1). These four reports included cases where patients were ventilated with medical air in an emergency situation, or received medical air via a face mask for an extended period of time.

**Table 1: Incidents reported to the NRLS between 1 January 2013 and 15 June 2016, in which oxygen tubing had been connected to air flowmeters**

| Reported degree of harm | No harm | Low | Moderate | Death | Severe | Total      |
|-------------------------|---------|-----|----------|-------|--------|------------|
|                         | 142     | 44  | 18       | 2     | 2      | <b>208</b> |

Two example reports are:

“... gentleman with severe sepsis with multi-organ failure. In-hospital cardiac arrest with 12 minutes of downtime. Post arrest, patient ventilated with Waters circuit which was incorrectly connected to wall medical air rotameter instead of wall oxygen unit. Mistake only noted after 30 minutes of ventilation via Waters circuit. Patient oxygen saturations 45-55% for at least 20 minutes” **[reported as resulting in severe harm]**.

“... On arrival patient was grey, clammy and agitated. A non-rebreathe mask was in situ and had been set at 10 litres/min. The Medical Registrar was asked to urgently review the patient. On arrival he reviewed the patient, ordered a CXR and contacted ITU Registrar to review as it was thought the patient had had a massive pulmonary embolus.... When the patient had died and equipment was being cleared away it was discovered that the non-rebreathe bag had been connected to the air port, no oxygen port was present and the air port had a nebuliser and oxygen tubing wrapped around it, obscuring it” **[reported as resulting in death]**.

The error in many of the ‘no harm’ incidents was identified quickly and patients did not seem to suffer any harm, but among these incidents there were cases describing patients in respiratory distress due to low oxygen saturation levels. For example:

“Patient’s oxygen required increasing and changing from a nasal cannula to oxygen mask. Staff Nurse changed and connected to different wall port. Deputy sister checked patient two hours later. It was noticed colour change to face, decreased oxygen saturations and oxygen mask attached to air port not oxygen **[reported as resulting in no harm]**.”

Most incidents occurred on medical wards (n = 91), followed by emergency departments (n = 65). Incidents were also reported from intensive care/high dependency units (n = 18), surgical wards (n = 17) and other clinical areas, including obstetrics/gynaecology and diagnostic units (n = 17).

Many of the incident descriptions were brief, merely stating that a patient had inadvertently been given medical air, without providing details about the situation, root causes or any planned actions. For example:

“Patient supposed to be on oxygen therapy, nasal cannula attached to piped air supply instead of piped oxygen supply.”

A summary of the circumstances described in these incident reports is given below.

### **Situations in which medical air was been given instead of oxygen**

Most incidents occurred when patients required continuous oxygen therapy to treat or prevent hypoxia. Other incidents occurred:

- during resuscitation
- during intubation
- after receiving medication via a nebuliser connected to the air outlet
- during sedation requiring 100% oxygen
- after return to the ward from other areas (eg radiology or theatre).

### **Why incidents occurred**

The factors reported as contributing to the occurrence of these incidents include:

- similar looking air and oxygen flowmeters
- faded lettering identifying the medical gas
- staff not trained in the use of medical gases or unfamiliar with the set up/equipment. For example, oxygen therapy was administered by staff who were not normally responsible for doing this or staff accompanying patients to the ward and then attaching the tubing to the wrong gas (eg emergency department, theatre, ambulance staff).
- oxygen and air flowmeters both present in the wall outlet. In some cases the policy was to remove the flowmeter when not in use, but this policy had not been implemented effectively. For example, one incident occurred after an air flowmeter had not been removed after a patient's discharge
- no oxygen flowmeter present when needed, only an air flowmeter



- air flowmeter covered by nebuliser and oxygen tubing.

Several reports described incidents happening despite barriers being put in place. This suggests these barriers on their own are not effective in preventing misconnections. Examples include:

- labelling of the air flowmeter
- flaps to prevent accidental use
- signs identifying the air and oxygen point
- training and awareness raising.

### **Reported actions taken by trusts to prevent similar incidents from happening in future**

Reported actions include:

- keeping air flowmeters away from a patient's bedside and only inserting them into the wall outlet when required
- occlusion of air ports with non-removable discs in as many cases as possible
- labelling flowmeters and putting clips over air outlets to increase awareness
- including the removal of air flowmeters in checklists (eg bed cleaning checklist)
- reducing the need for medical air outlets by using compression or ultrasonic nebulisers
- leaving oxygen flowmeters in place in all oxygen outlets ready for immediate use.

### **Additional risks identified**

#### **Confusion between oxygen cylinders and air cylinders**

In the sample of incidents reviewed some reports described medical air and oxygen cylinders being confused. It was only when the patients saturation levels were found to remain low that it was discovered they were receiving gas from a medical air cylinder and not an oxygen cylinder.

“Emergency medical response team (EMRT) called to patient having anaphylactic reaction. No wall O<sub>2</sub> on ward so F size cylinder bought and attached to patient using high flow mask. Sats were 80% and not increasing so cylinder checked, the cylinder being used was air not oxygen.”

In some cases the wrong flowmeter had been attached, ie an oxygen flowmeter was connected to a medical air cylinder and vice versa. Incident descriptions have suggested this could be prevented by improving the labelling of cylinders and improving staff vigilance with awareness campaigns and training. However, as the same risk of confusing medical gases can apply to portable gases, and the barriers suggested above are not very strong, we suggest trusts consider reducing the risk by avoiding the use of medical air cylinders as far as possible.

### **Risks arising from removal of air flowmeters/medical air outlets**

There were two incidents in the reviewed sample that described the non-availability of air flowmeters/medical air outlets as being responsible for patients at risk of hypercapnia receiving medication nebulised with piped oxygen. These incidents highlight the need for careful implementation of this alert to ensure that no new risks arise from covering medical air outlets or storing air flowmeters in an allocated place before alternative equipment for delivering nebulised medication has been provided.

### **Wider aspects of oxygen safety**

In the sample of incidents reviewed reports described the incorrect gas selection when using a nebuliser. In particular:

- discontinuation of oxygen supply to patients dependent on very high levels of oxygen to maintain adequate saturation because nebuliser therapy was driven by medical air not oxygen
- patients at risk of hypercapnia (eg those with severe COPD) receiving nebulised medication through high flow oxygen, not air – with nasal oxygen if necessary.

Staff involved in these incidents appeared not to be misidentifying the flowmeters but instead were incorrectly applying a 'rule' that all patients should receive nebulised medication using air. There also seemed to be a lack of knowledge around appropriate use of these gases, eg some staff were unaware that giving high flow oxygen to patients with severe COPD can be fatal.

The risk of selecting the wrong gas for nebulisers was previously highlighted by the NPSA.<sup>2</sup> Suggestions have been made to support the safe administration of nebulised drugs, including specifying the driving gas for nebulised therapy in the prescription and developing a group directive. NHS organisations may wish to review their local policies and practice to ensure that staff have clear guidance on the use of nebulisers.

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<sup>2</sup> Patient safety resources (2013) *Selecting 'oxygen' or 'medical air' to give nebulisers* | Signal <http://www.nrls.npsa.nhs.uk/resources/?EntryId45=134717>

While the focus of this directive alert is on changes to equipment to reduce the risk of accidental connection to the wrong gas supply, these incidents underline the importance of continued wider work to improve the safety of patients who require medical air. The 2009 NPSA RRR on Oxygen safety in hospitals<sup>3</sup> required the establishment of a multidisciplinary group (such as a medical gas committee) responsible for reviewing oxygen-related incidents, and developing a local oxygen policy and a training programme. These groups remain key to improvements in safety, and such groups may wish to use this directive alert as part of a wider report to their board (or equivalent) on their progress and achievements in improving safety.

## Rationale for alert requirements

The actions required by the alert apply to all healthcare providers (both in the NHS and private sector) that supply medical air from MGPS.

**Action 1:** Identify a named individual who will take responsibility for co-ordinating the delivery of the actions required by this alert.

This action is included because incident reports have shown that new risks to patient safety can be introduced if actions required by an alert are not carefully implemented and managed, and the changes required by this alert will require careful co-ordination across what may be multiple sites and specialties in larger hospital providers. We recommend that a named individual takes responsibility for co-ordinating the delivery of the actions. The most appropriate individual to undertake these responsibilities and the support they will require will typically be best identified by an existing multidisciplinary group (eg the medical gas committee in acute trusts, or a clinical governance group in a community hospital or independent hospital provider).

**Action 2:** Implement systems to ensure that the **three barriers** to human error described in this alert are **all** in place in all relevant clinical areas.

The text in the alert lists three barriers:

### **1. In areas where there is no need for medical air, cover the medical air terminal units (wall outlets) with designated caps**

Medical air outlets have been built into most clinical areas for the delivery of nebulised treatment. However, not all areas provide such treatment or alternatives have superseded the use of piped air (eg electrically driven compressors or ultrasonic nebulisers). As there is no need for medical air in these areas any outlets should be covered.

<sup>3</sup> <http://www.nrls.npsa.nhs.uk/alerts/?entryid45=62811>

Various caps on the market can be inserted into the terminal unit (wall outlet). These include:

- **Locking plugs.** The plug can only be unlocked with a special key and this only needs to be done when medical air is needed in the clinical area. In areas where medical air is not currently needed, locking plugs seem to be the most effective preventative method as it is unlikely they would be removed without good reason or authorisation.
- **Removable blanking plugs.** These plugs can be removed by hand. Some trusts use this type of plug when the air flowmeter has been removed and the medical air outlet is not in 'actual' use. Some areas attach these plugs to the flowmeters with a lanyard to prevent them from getting lost.

While the alert requires hospitals and any other relevant sites to cover medical air outlets in areas where there is no need for medical air, whether to cover medical air outlets 'between uses' is a local decision, not a requirement for compliance with this alert.

The NHS Estates and Facilities team (Department of Health) suggests that in addition to covering medical air terminal units (wall outlets) with caps, the medical air supply can be turned off in areas where it is not needed. Trusts might consider this as an action option as part of their implementation of the alert. If a decision is taken to turn off/isolate the medical air supply the system will need to be recommissioned if it is reinstated in the future. The medical air pressure alarms will also need to be deactivated.

## **2. Medical air flowmeters are removed from terminal units (wall outlets) and stored in an allocated place when not in active use**

Several trusts have implemented the policy of removing air flowmeters from outlets when not in use, but their local approaches to this vary.

In some cases a flowmeter is left in situ and not removed between a patient's regular nebulised therapies; that is, it is left in place throughout a patient's hospital stay. In other cases policies have been implemented that only allow the flowmeter to be in the terminal unit (wall outlet) during active use of medical air and as soon as the nebulised treatment finishes the flowmeter must be removed and stored until required again.

By using the phrase 'not in active use' the alert is recommending the approach of removing the flowmeter except for the short period required to actually deliver each dose of nebulised medication rather than that of leaving it in situ. This is because those patients who regularly need nebulised medication are at risk of acute respiratory problems and might require oxygen routinely or urgently. Leaving the air

flowmeter in place for the hours when a patient is not using a nebuliser will do little to reduce the risk of accidental connection to the air outlet when oxygen is required.

This barrier is important as removing unnecessary equipment is known to be more effective in reducing human error than labels or warnings alone, even if the latter involve lifting a flap or clip (see the third barrier below). We appreciate there might be unusual clinical situations where always removing the flowmeter might not be appropriate or feasible. In such cases, we suggest that alternative options are considered and local arrangements are made that reflect the principles of this barrier.

Best practice would be to identify allocated storage for flowmeters away from the bedside (eg in a store room or store cupboard). In some cases where medical air flowmeters are used frequently, special storage has been designed beneath the terminal unit. Staff are then able to remove the flowmeter from the wall outlet but have easy access for frequent use of nebulisers.

When implementing this barrier in clinical areas where medical air flowmeters are available, staff must be made aware of the storage location and that air flowmeters are now less accessible to reduce the risk of inadvertent use.

### **3. Air flowmeters are fitted with a labelled, movable flap**

There are two reasons why a flap can provide a further barrier to prevent oxygen tubing being inadvertently connected to a medical air flowmeter. First, the flap is labelled 'medical air' in lettering larger than that on the flowmeter itself, making it more visible to staff. Second, the flap has to be lifted to attach a tube, which is an additional step to prompt the user to check the outlet supplies the correct type of gas.

In theory, flaps would not need to be fitted if the other two barriers are always put into practice. If all 'out of use' medical air outlets are covered and all flowmeters are always removed from the outlet after active use, the risk of inadvertently attaching an oxygen tube to an air flowmeter would be low. However, we know that there will be occasions when air flowmeters might accidentally be left in situ, eg when staff are distracted or not fully aware of local arrangements.

We recommend that flaps are fitted to all air flowmeters remaining in use. We understand from trusts that have implemented this barrier that the cost of purchasing and installing the flaps is not excessive. Flap installation may need to be co-ordinated with the terminal unit manufacturer to avoid any fouling of tubing. There are various products on the market and price and compatibility with existing systems will influence choice. For example, some air flaps are manufacturer specific, while others are 'universal' – this is especially important when considering retro-fitting.

During the consultation period for this alert the use of **terminal unit warning labels** was also suggested. Some trusts have designed these in-house and used their usual print supplier to create them.

**Figure 2: Example of a terminal unit warning label**



Similarly to the use of flaps on medical air flowmeters, labels have a limited impact on reducing human error when implemented on their own. They can however be effective if used in combination with other approaches as they help to differentiate between different gas outlets.

Note: while the alert requires the implementation of all three barriers, that requirement is of course only intended for hospitals and any other sites where flowmeters remain in use in at least some locations. If an organisation has completely eliminated the use of medical air and has removed or locked all its air outlets and air cylinders (as some hospitals have done), no further barriers to this error are required.

**Action 3:** Establish ongoing systems of audit or equipment checks to ensure the barriers are maintained.

Some trusts are already carrying out regular audits of medical gases and suction equipment, including the barriers outlined in this alert. Audit should assess if:

- unused medical air outlets are covered with a designated cap
- medical air flowmeters are removed from terminal units (wall outlets) and stored in an allocated place when not in active use
- all flowmeters have been fitted with a labelled, movable flap.

**Action 4:** Share what you learn from implementing this alert or locally developed good practice resources by emailing [patientsafety.enquiries@nhs.net](mailto:patientsafety.enquiries@nhs.net)

If you can offer any resources or ideas to support others to implement the actions of the alert, or if you have any questions, please email the patient safety team ([patientsafety.enquiries@nhs.net](mailto:patientsafety.enquiries@nhs.net)).

## Local implementation examples

### Great Western Hospitals NHS Foundation Trust

Following an incident involving confusion between air and oxygen, Great Western Hospitals NHS Foundation Trust took action to make its systems safer. The trust found that many of its medical air outlets were no longer used; for example, nebulised drugs are now given via electrically-driven devices. In these areas air outlets have been covered with lockable caps. The caps were supplied in packs of 50 and cost about 50p each.

**Figure 3: Air outlets have been locked in some areas**



Medical air terminal units in ITUs, theatres and other critical care areas were not capped as these still use piped air for ventilators and other equipment. For certain wards where medical air terminal units are still used (eg respiratory wards), flowmeters have been purchased with a flap/shield/guard. These are labelled 'medical air' and as this lettering is larger than on the flowmeter itself, it is easier to differentiate between air and oxygen flowmeters. Also, when attaching a tube the flap needs to be lifted, which is an additional step to remind the user that they are designed for a different gas supply.

**Figure 4: Only safer air flowmeters are now in use**



The trust spent approximately £1,500 on implementing these changes in its 600-bed hospital.

For technical queries, you may contact the trust's Medical Device Safety Officer, John McGinty at [john.mcginty@gwh.nhs.uk](mailto:john.mcginty@gwh.nhs.uk)

For clinical queries you may contact Dr Mark Juniper, Consultant in Respiratory and Intensive Care Medicine at [Mark.Juniper@gwh.nhs.uk](mailto:Mark.Juniper@gwh.nhs.uk)



## Colchester Hospital University NHS Foundation Trust

Colchester Hospital University NHS Foundation Trust has taken the following actions to minimise the confusion between air and oxygen flowmeters:

- the risk is included in the trust's Induction & Refresher training to raise awareness to the problem
- staff are required to complete an Equipment Competency before operating the equipment on a patient, which includes oxygen/air flowmeter
- air flowmeters are only held in restricted wards/departments and in limited numbers
- air flowmeters are not fitted routinely in those areas; they are stored locally in a central location until required and then removed and stored once the activity is completed
- medical air flowmeters are fitted with a labelled movable 'guard' that covers the tubing connection to raise awareness of the type of gas selected
- air blanking plugs are fitted to all unused outlets. These plugs are clearly labelled 'Medical Air Devices Only' which further prompts staff to think about the device they are connecting and the gas they want to use
- compliance checks are completed during oxygen wastage audits.

**Figure 5: Medical air flowmeters are fitted with a labelled, movable 'guard' that covers the tubing connection to raise awareness of gas selected (left) and air blanking plugs are fitted to all outlets not in use**



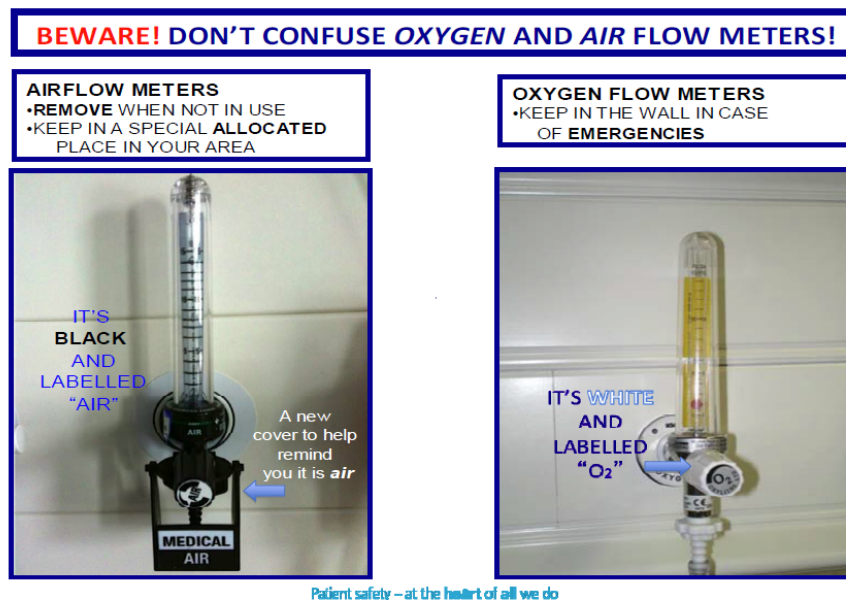
For further information you may contact the Electro-Biomedical Engineering (EBME) Operational Manager, Steven Connew at [steven.connew@colchesterhospital.nhs.uk](mailto:steven.connew@colchesterhospital.nhs.uk)

## Cambridge University Hospital NHS Foundation Trust

Cambridge University Hospital NHS Foundation Trust issued an internal alert in March 2014 to minimise the confusion between air and oxygen flowmeters. The alert requested that:

- each air flowmeter in the trust has a black guard attached that is clearly labelled clearly 'Medical Air'
- flowmeters are removed from the wall outlet and stored in an allocated place when not in use.

Pictures showing the warnings and instructions were printed on the back of the local alert:



For further information you may contact the trust's Medical Device Safety Officer, Adam Armstrong at [adam.armstrong@addenbrookes.nhs.uk](mailto:adam.armstrong@addenbrookes.nhs.uk)



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