1. Introduction and Who Guideline applies to

1.1 This guideline and competency assessment has been developed for use by Nurses, Doctors and Physiotherapists who are required to use a Mapleson-C bagging circuit to use manual hyperinflation (MHI) as a treatment modality in adult patients ventilated by endotracheal tube or tracheostomy.

1.2 All University Hospitals of Leicester Physiotherapists Band 5 and above working within the respiratory service must be assessed as competent to use all the techniques in this guideline. This includes non- respiratory staff with respiratory weekend and on-call responsibilities, across all three UHL hospital sites. Competency must be assessed by a Clinical Specialist Physiotherapist and recorded on the associated competency framework document.

1.3 Any Nurses or Doctors who are required to use manual hyperinflation within their routine practice should be formally assessed by a Senior Physiotherapist, Doctor or Nurse who has been assessed as competent themselves, using the associated competency framework document.

1.4 All staff should adhere to trust and individual department standard operating procedures (SOP) and/or guidelines regarding infection prevention and personal protective equipment such as the SOP for therapists delivering airway clearance techniques.

2. Guideline Standards and Procedures

2.1 Manual hyperinflation involves the use of a Mapleson-C bagging circuit to encourage alveolar recruitment and proximal movement of airways secretions. This is achieved by delivery of a high volume inspiration, inspiratory hold, and quick release expiration.

2.2 The high volume inspiration should be delivered slowly, at a low flow rate to avoid barotrauma and encourage laminar airflow.

2.3 The inspiratory hold allows intrathoracic pressure to equalize, opening channels of collateral ventilation and encouraging alveolar recruitment.

2.4 Despite the name of the technique, the aim is not to 'hyperinflate' or over distend the lungs. Peak pressures should not exceed 40cmH_2O.

2.5 High risk patients with severe acute lung injury, pre-existing lung disease, acute respiratory distress syndrome secondary to COVID-19 or cardiovascular instability may need lower pressures, and this should be discussed with the Intensive Care Consultant, with the discussion and the agreed pressure limit documented clearly.

2.6 The quick release of the bag produces rapid, expiratory airflow. This subsequent expiratory flow bias moves secretions proximally towards the larger airways, where it can be aspirated from the lungs using suction.

2.7 The physiological principle is that of two-phase gas-liquid flow; whereby altering the pattern of airflow determines the movement of the liquid (secretions) within the airways (fig 1). A normal cough generates very high expiratory airflow, which creates mist flow of the secretions to enable them to be expelled from the airways. However, the expiratory flow generated with MHI is still much slower than a normal cough, and so moves secretions using annular flow instead. MHI may therefore prevent mucus plugging and associated lobar collapse (Paulus et al, 2012).

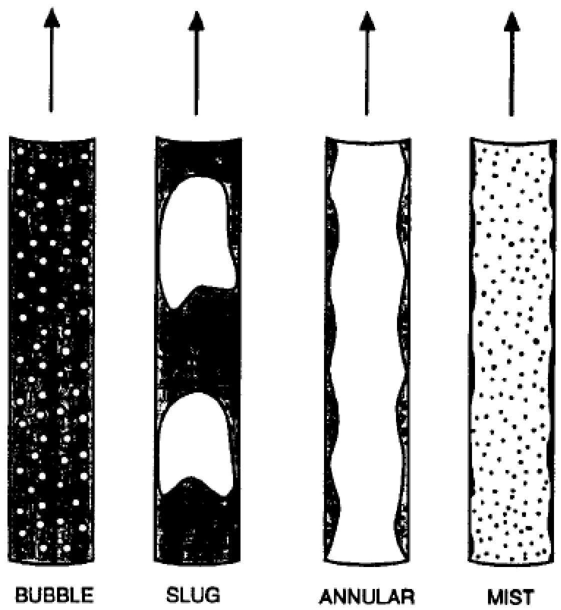

Fig. 1. Diagrammatic representation of types of two-phase gas–liquid flow.

Leith (1968)

2.8 Indications

a) Clearance of retained secretions and mucus plugging (Hodgson et al, 2000)
b) Recruitment of areas of atelectasis or collapse
c) To improve ventilation/perfusion (V/Q) matching
d) To improve lung compliance (Hodgson et al, 2000)
e) To improve regional lung ventilation
f) To improve oxygenation

2.9 Contraindications

a) Emphysematous bullae
b) Diagnosis of ARDS/Fibrosis/other condition with reduced compliance
c) Subcutaneous emphysema
d) Undrained pneumothorax
e) Open bronchopulmonary fistula
f) Unexplained haemoptysis
g) Lung abscess

h) Inverse ratio ventilation or APRV

i) PEEP ≥-12 cmH_2O

j) Peak airway pressures ≥ 40cmH_2O on mechanical ventilation

k) Acute bronchospasm

l) Systolic BP of 80mmHg or below

m) Uncontrolled arrhythmia

n) Right heart failure

o) Agitation / aggression

2.10 The following patient groups should be considered high risk, and MUST be discussed with the Intensive Care Consultant before treatment.

a) Patients receiving ECMO (to be discussed with the on-call ECMO Consultant)

b) COPD

c) Recent cardiac or thoracic surgery

d) Drained pneumothorax

e) Fractured ribs/flail segment

f) Head injury

g) Dependent on PEEP ≥ 8 cm H20

h) Oxygen requirement of ≥60 % concentration

i) COVID-19

2.11 The following assessments should be undertaken before, after, and where appropriate, throughout the duration of treatment.

a) Observation of the patient (including respiratory distress, fatigue, neurological status and work of breathing)

b) Airway pressure readings from ventilator or manometer

c) Auscultation

d) Cardiovascular stability

e) Oxygen saturations

f) Respiratory rate

g) Arterial blood gases

h) End-tidal CO_2

i) Consistency/colour of secretions

2.12 To use the techniques above, the following equipment will be required.

a) Mapleson-C bagging circuit (Fig. 2)
b) Manometer (Fig.3) (within Mapleson-C pack, but needs placing in circuit prior to use). A manometer MUST be placed in EVERY circuit.
c) Bacterial/HME filter (Fig. 4)

Fig.2

Fig.3

Fig.4

d) The circuit will come set up as shown in Fig.5, with the manometer placed in the circuit as shown in Fig. 6.

Fig. 5

Attach to O2 flow meter and turn flow up to

15l/min

Use APL valve to adjust the pressure in the bag and therefore adjust the PEEP

Remove the red safety cap and attach the filter. Then attach the catheter mount from the patient's circuit.

Place the manometer between the HME filter and the catheter mount

Fig. 6

2.13 Procedure

Manual Hyperinflation *(Adapted from Main et al, 2016)*

This technique is a treatment modality and should only be used by health professionals who have been assessed as competent in its use. If you are unsure, seek advice from your Physiotherapist. Please note that ECMO patients must not be bagged without prior discussion with the on-call ECMO Consultant.

ACTION	RATIONALE
1. Ensure patient is appropriate to be disconnected from the ventilator at this time.	If the patient has a high PEEP dependency ($\geq$8cmH_2O), is on $\geq$60% oxygen concentration, or is cardiovascularly or neurologically unstable, it may be safer to delay non-essential disconnection and reassess the patient again later.
2. Ensure MHI is appropriate for your patient. See indications, contraindications and precautions for details. If the patient is high risk, you MUST discuss your treatment plan with the Intensive Care Consultant first and clearly document the conversation. If you are unsure if your patient is suitable for MHI, please discuss with a Clinical Specialist Physiotherapist.	MHI can cause barotrauma, pneumothoraces, and medical instability. Patients with pre-existing lung disease, following recent cardiac surgery, or those on ECMO, are considered very high risk for MHI and should always be discussed. Please refer to the full list of contraindications and precautions.
3. Follow the relevant Infection prevention procedures for the patient as per UHL Trust Infection Prevention Policy. (Trust Ref B9/2006)	Gloves and an apron should always be worn to protect yourself and the patient. It may be necessary to wear a face mask for some patients. You should ensure you have been assessed and fitted with the appropriate mask for your protection.
4. Auscultate, and ensure there is no undrained pneumothorax on the patients most recent chest x-ray. Consider the positioning, conscious state, and pain control of your patient. Ensure you inform the patient of what you are doing, and obtain consent where possible.	Checking the chest x-ray and auscultating are important safety measures and will help you to assess the effectiveness of your treatment. Ensuring your patient is informed and comfortable will improve compliance with treatment.
5. Remove the red safety cap from the patient end of the circuit and attach filter. Attach green tubing from the Mapleson-C circuit to the oxygen flow meter, and turn the flow up to 15l/min. Cover the patient end of the circuit with your gloved hand to ensure that the bag inflates.	This ensures the circuit is correctly assembled before connection to the patient. Please refer to the troubleshooting section if you detect a problem with the circuit.

ACTION	RATIONALE
6. Disconnect the patient from the ventilator, and attach the patient end of the circuit to the end of the catheter mount. You may need help from a second person to do this. Start manual ventilation straight away. You may need to silence the ventilator alarms, or put the ventilator on standby temporarily.	The patient may not be taking any spontaneous breaths, so it is important to start manual ventilation straight away. It is important to silence the ventilator alarms following disconnection to ensure the patient remains calm. You should follow the guidance for your ICU on whether to silence the alarms or put the ventilator on standby.
7. Squeeze the green bag with one hand. The bag holds 2l of oxygen, so you do not need to empty the bag completely when you squeeze. Adjust the APL valve to ensure you have enough pressure in the bag to deliver an adequate tidal volume, but not so much pressure that the bag is stiff and difficult to squeeze. Use the manometer to guide how hard you squeeze the bag – remember you should not be generating pressures of more than 20-25cmH_2O during manual ventilation.	Manual ventilation is purely to maintain adequate ventilation whilst disconnected from the ventilator, so excessive pressures or hyperinflation should not be used at this stage.
8. You should aim to deliver 12-18 breaths per minute. If the patient is taking spontaneous breaths, you may be able to synchronise with their breathing.	Delivering a very fast respiratory rate can cause hyperventilation and patient distress. Likewise, a rate that is too slow can cause hypoventilation and impair gas exchange. Synchronising the breaths you deliver with the patient's own breathing helps to improve comfort.
9. Monitor the patient closely for end tidal CO_2, equal chest movement, acceptable oxygen saturations, cardiovascular and neurological stability. If stable, you can begin MHI.	Any deterioration needs to be identified quickly to ensure timely return to the ventilator and assistance from the medical team.
10. Squeeze the bag slowly and twist to deliver greater air flow into the patient's lungs. Again, if your patient is taking spontaneous breaths, you should try to synchronise with their breathing.	A slow delivery of the breath reduces the risk barotrauma, improves flow through collateral channels of ventilation, and helps generate an expiratory flow bias to move secretions.
11. Check the manometer to ensure you are not exceeding a pressure 40cmH_2O, or the pressure agreed with the Intensive Care Consultant if different.	Pressures above 40cmH_2O may cause barotrauma. Patients who are high risk may require much lower pressures to reduce the risk of barotrauma or instability.

ACTION	RATIONALE
12. Hold the bag at the end of inspiration for up to 3 seconds, before releasing quickly. Repeat this sequence for 6 breaths, then return to manual ventilation before suctioning. You may feel or hear secretions while you are bagging; you can also use this to guide when you need to suction.	An inspiratory hold utilises collateral channels of ventilation. The quick release of the bag creates an expiratory flow bias which mimics airflow during a cough and helps to move secretions proximally. You may need another person to help suction, particularly if your patient is not taking spontaneous breaths.
13. When your treatment is complete, you should turn the ventilator back on if it has been on standby, and check all settings are correct before returning the patient to the ventilator. Inform the patient this is what you are doing.	These are important safety checks as settings may have been altered accidentally during disconnection. Informing the patient helps to improve synchrony on return to the ventilator.
14. Once the patient is safely back on the ventilator, you can start to pack away the bagging circuit. Ensure the HME filter is not left in the patient's circuit, particularly if they are on a wet circuit.	The red safety cap should be placed back onto the patient end of the Mapleson-C circuit for infection control purposes. Leaving a HME filter in the circuit can cause it to become water-logged and impair ventilation.
15. Auscultate after your treatment and report any concerns immediately to the medical team.	This ensures there is good air entry, no evidence of pneumothorax, and assesses the effectiveness of treatment.

2.14 Troubleshooting

Problem	Possible cause	Action
Inadequate tidal volume	APL valve open too far	Close APL valve more
	Inadequate flow rate	Ensure flow meter connected at 15l/min
	Punctured bag	Check bag for punctures, return patient to ventilator immediately if puncture discovered
	Other problem with circuit	Check all circuit connections
Bag over-inflating	APL valve too far closed	Open up APL valve
Resistance to inspiratory flow	Poor lung compliance i.e. bronchospasm	Check pressures on manometer for safety, return to ventilator immediately
	Obstructed ET tube/trache	Try to suction to clear the airway, if resistance remains, return patient to ventilator and inform medical team
	Expanding pneumothorax	Return to manual ventilation and auscultate, return to ventilator if pneumothorax suspected
Clinical deterioration of patient	Mucus plugging (“plugging off”)	Attempt to clear with further bagging and suction, if unable to clear, patient should be returned to ventilator and medical team called
	Cardiovascular instability	Return to manual ventilation bagging, if no improvement, return to ventilator and inform medical team
	Pneumothorax	Return to manual ventilation and auscultate. If pneumothorax suspected, return patient to ventilator and inform medical team
	Bronchospasm	Return to manual ventilation and administer Salbutamol nebuliser if prescribed and appropriate. Cease treatment and return to ventilator if unable to control bronchospasm
	Respiratory distress	Try to synchronise breaths with patient, if unable, return patient to ventilator

3. Education and Training

Training and competency assessment in line with the guideline will be provided to physiotherapy staff within respiratory on-call training, to medical staff within initial induction, and to ICU nursing staff in their second year of ICU training. Assessment of competence will be against the following statements:

- Knowledge
  a. Understands the indications for MHI
  b. Understands the contraindications for MHI
  c. Understands the precautions and high risk patient groups when considering MHI
  d. Aware of the risks and complications of MHI and how these can be addressed
  e. Demonstrates good clinical reasoning in the use of MHI
  f. Demonstrates sound knowledge of the limitations of treatment and appropriate alternatives
  g. Understands the physiology of MHI, and the physiological changes in the patient during and after MHI
  h. Demonstrates good knowledge of respiratory anatomy
  i. Demonstrates knowledge of which clinical parameters to monitor before, during and after MHI
  j. Demonstrates knowledge of necessary actions in the event of a medical emergency during MHI
- Preparation
  a. Assembles Mapleson-C circuit correctly with manometer and filter in the circuit
  b. Attaches the circuit to an O_2 supply at the correct flow rate
  c. Ensures the circuit is functioning correctly before connection to the patient
  d. Undertakes baseline observations of patient
  e. Auscultates and checks most recent chest x-ray prior to treatment
  f. Positions patient for optimal treatment effect and comfort
  g. Observes infection control procedures
- Demonstration of technique
  a. Attaches the circuit to the patient, silencing the ventilator alarms or placing on standby as appropriate
  b. Demonstrates competent MHI technique
  c. Able to assess pressures delivered accurately using manometer
  d. Able to adjust APL valve accordingly to increase/reduce to desired pressure
  e. Selects and competently applies adjuvant therapy techniques appropriately
  f. Monitors relevant clinical parameters throughout treatment
  g. Monitors treatment effectiveness, need for modification or discontinuance
  h. Able to problem solve any issues, and takes appropriate action in response to adverse reaction to MHI
  i. Communicates effectively with MDT colleagues where two or more operators are required for treatment

j. Reconnects patient back to ventilator correctly following treatment
k. Records post-treatment observations, including re-auscultation
l. Cleans equipment in line with infection control policy
m. Correct disposal of waste

- Records
  a. Correct and legible note-writing
  b. Documentation of manometer pressures
  c. Documentation of patients observations before, during and after treatment
  d. Documentation of communication with doctor and agreed pressure limits if high risk patient identified
  e. Feedback given to medical team following treatment if high risk patient
  f. Treatment plan clinically reasoned and documented

Competency frameworks can be obtained from the Education & Practice DevelopmentTeam
No formal refresher training is required.

4. Monitoring Compliance

What will be measured to monitor compliance	How will compliance be	Monitoring Lead	Frequency	Reporting arrangements
Presence of manometer in Mapleson-C circuit	Spot-check audit	Clinical Specialist Physiotherapist	Yearly	To ICU Core Group
Completion of competency assessment	Audit of staff with completed competency	Clinical Specialist Physiotherapist	Yearly	To ICU Core Group

5. Supporting References

1. Dreyfuss D and Saumon G. High inflation pressures and pulmonary oedema. Respective effects of high airway pressure, high tidal volume and PEEP. American Respiratory Review of Respiratory Disease 1988; 137: 1159-1164
2. Goodnough SK. The effects of oxygen and hyperinflation on arterial oxygen tension after endotracheal suction. Heart and Lung 1985; 14: 11-17
3. Haake R et al. Barotrauma: Pathophysiology, risk factors and prevention. Chest 1987; 91: 608-613
4. Hodgson C et al. An investigation of the early effects of manual lung hyperinflation in critically ill patients. Anaesthesia and Intensive Care 2000; 28: 255-261
5. Jones A, Hutchinson R and Oh T. Effects of bagging on total static compliance of the respiratory system. Physiotherapy 1992; 78: 661-666
6. King D and Morrell A. A survey on manual hyperinflation as a physiotherapy technique in intensive care units. Physiotherapy 1992; 78: 747-750
7. MacLean D et al. Maximum expiratory airflow during chest physiotherapy on ventilated patients before and after the application of an abdominal binder. Intensive Care Medicine 1989; 15: 396-399

8. Main, E. and Denehy, L. (2016) Cardiorespiratory Physiotherapy: Adults and Paediatrics. 5th Ed. London: Elsevier.
9. Maxwell L and Ellis E. Secretion clearance by manual hyperinflation: Possible mechanisms. Physiotherapy Theory and Practice 1998; 14: 189-197
10. McCarren, B. and Chow, C.M. (1998). *Description of manual hyperinflation in intubated patients with atelectasis* .Physiotherapy Theory and Practise 14 199-210.
11. Novack RA et al. Do periodic hyperinflations improve gas exchange in patients with hypoxaemic respiratory failure ? Critical Care Medicine 1987; 15:1081-1085
12. Partaz J. Haemodynamic stability of the ventilated intensive care patient: A review. Australian Journal of Physiotherapy 1992; 1992: 167-172
13. Paulus,F., Binnekade, J.M., Vroom, M.B. & Schultz MJ (2012) Benefits and risks of manual hyperinflation in intubated and mechanically ventilated intensive care unit patients: a systematic review. Critical Care, 16 (4), R145.
14. Redfern J et al. The use of a pressure manometer enhances student physiotherapists' performance during manual hyperinflation. Australian journal of physiotherapy 2001; 47: 121- 131 MHI Guidelines 2015
15. Rothen HU et al. Re expansion of atelectasis during general anaesthesia: A computer tomography study. British Journal of Anaesthesia 1993; 71: 788-795
16. Rusterholz B and Ellis E. The effect of lung compliance and experience on manual hyperinflation. Australian Journal of Physiotherapy 1998; 44: 23-28
17. Scholten W et al. Directed manual recruitment of collapsed lung in intubated and non intubated patients. Annals of Surgery 1985; 51: 330-334
18. Singer et al. Haemodynamic effects of manual hyperinflation in critically ill mechanically ventilated patients. Chest 1994; 106: 1182-1187 Stiller K et al. Acute lobar atelectasis: A comparison of two chest physiotherapy regimes. Chest 1990; 98: 1336-1340
19. Stone KS et al. Effect on lung hyperinflation and endotracheal suctioning on heart rate and rhythm in patients after coronary artery bypass graft surgery. Heart and Lung 1991; 20: 443-450
20. UHL Infection Prevention Policy (Trust Ref B9/2006)
21. UHL Therapists Delivering Airway Clearance Techniques (Therapies SOP)

6. Key Words

Manual ventilation, manual hyperinflation, intensive care, physiotherapy.

CONTACT AND REVIEW DETAILS	
Guideline Lead Anna Makower, ClinicalSpecialist Physiotherapist	**Executive Lead** Lynne Cooke, Head of Therapies
Details of Changes made during review: N/A – new guideline approved on 17 March 2017 (Policy and Guideline Committee) September 2018 – review June 2021 – review no changes made.	