

A survey of the use of ventilator hyperinflation in Australian tertiary intensive care units

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Manual hyperinflation (MHI) or “bagging” has been used by physiotherapists as part of the routine respiratory management of artificially ventilated patients in the Australian intensive care unit setting since the early 1970s.¹ It involves the delivery of larger than normal volumes of gas to intubated patients via a resuscitation circuit and aims to improve lung oxygenation, reverse lung collapse and clear lung secretions.² There is extensive literature supporting the efficacy of MHI and the consistency of its implementation by physiotherapists.³ Hodgson et al³ found that 91% of physiotherapists in 32 Australian teaching hospitals used the technique.

Hyperinflation using a ventilator (VHI) is, by comparison, a relatively new technique. It was first described in the literature in 2002⁴ and then again in 2006,⁵ when it was compared with MHI and found to have similar effects on measures such as sputum volumes, haemodynamics and oxygenation.^{4,5} More recently, its efficacy was compared with positioning alone.⁶ Despite relatively little published data, anecdotal accounts indicate that VHI is being used in some Australian ICUs.

The aim of our study was to ascertain the prevalence of use of VHI by physiotherapists practising in Australian tertiary ICUs in the management of artificially ventilated patients, and whether standard protocols were in place in these facilities.

Methods

We conducted a prospective, multicentre survey of the use of VHI in tertiary Australian ICUs to establish the frequency of VHI intervention and the protocol by which the technique was administered. This paralleled a study in 1999 of the use of MHI in Australian hospitals.³

Inclusions/exclusions

All 64 tertiary Australian hospitals with ICU facilities and attending physiotherapists were included in our study. There were no exclusions, as all of the tertiary facilities had physiotherapists in the ICU.

Process

A list of tertiary Australian hospitals with ICU facilities and their telephone numbers was compiled from details provided by the Australian and New Zealand Intensive Care

ABSTRACT

Objective: To ascertain the prevalence of use of ventilator hyperinflation (VHI) by physiotherapists practising in tertiary Australian intensive care units in the management of artificially ventilated patients, and whether standard protocols are in place in these facilities.

Design, setting and participants: A prospective, multicentre prevalence survey of 64 Australian hospitals with tertiary ICU facilities and physiotherapists. The cohort was compiled from details provided by the Australian and New Zealand Intensive Care Society Centre for Outcome and Resource Evaluation. Senior physiotherapists at participating sites completed a telephone questionnaire regarding the implementation of VHI at their facility.

Results: The response rate was 100%. Twenty-five facilities reported using VHI. There was broad agreement on the indications and contraindications for the technique and little difference in the dosage of VHI for the purpose of either sputum clearance or respiratory recruitment manoeuvre. The most common position used for treatment (71% of patients) was side lying with the affected side uppermost.

Conclusions: Our survey provides information on the nature and the extent of VHI utilisation by physiotherapists in Australian tertiary ICUs. These data can now be pooled to develop standardised evidence-based VHI protocols for both spontaneous and controlled ventilation modes.

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Society Centre for Outcome and Resource Evaluation. These facilities were telephoned by one of two senior physiotherapists with acute care experience to ascertain the most appropriate senior ICU physiotherapist at the participating site to complete the survey. This person was then invited to participate. There was no written consent, as the project was explained during the telephone call, the respondent's verbal consent was obtained, and providing answers to the survey was taken to imply consent.

Outcome measure

The questionnaire (Appendix 1) was developed in collaboration with senior physiotherapists working in the ICU at Sir

Table 1. Facilities using VHI, length of use and proportion of overall physiotherapy treatments using VHI, by state

	NSW	QLD	SA	VIC	WA	Other*	P
Tertiary ICUs, <i>n</i>	19	14	6	17	4	4	
ICUs using VHI, <i>n</i> (%)	5 (26%)	2 (14%)	1 (17%)	12 (70%)	3 (75%)	2 (50%)	0.006 [†]
Mean years of use (SD)	6.0 (3.0)	2.8 (1.8)	1.0 (0.0)	5.6 (3.9)	2.7 (0.6)	1.5 (1.9)	0.466 [‡]
Mean proportion of total treatments using VHI (SD)	35% (34%)	30% (28%)	20% (0%)	39% (30%)	70% (23%)	25% (38%)	0.570 [‡]

ICU = intensive care unit. NSW = New South Wales. QLD = Queensland. SA = South Australia. VHI = ventilator hyperinflation. VIC = Victoria. WA = Western Australia. * Northern Territory, Australian Capital Territory and Tasmania. † *P* value calculated using exact logistic regression analysis. ‡ *P* value calculated using Kruskal–Wallis test.

Charles Gairdner Hospital (SCGH), Perth, Western Australia, and was based on current literature pertaining to potential parameters for use in VHI and the manner in which VHI may be applied to mechanically ventilated patients.^{4,5} The survey consisted of 59 questions that could be completed over the telephone in less than 20 minutes. It was designed to determine indications, contraindications, precautions, dosage and the overall protocol used.

Ethics approval

The SCGH Human Research Ethics Committee approved the study.

Results

There was a 100% response rate to the survey (*n* = 64), with 25 facilities (39%) reporting the use of VHI. The number of facilities using VHI, the length of use, and proportion of physiotherapy treatments using VHI are summarised, by state, in Table 1. Because of the low number of centres in the Northern Territory, Australian Capital Territory and Tasmania, these three jurisdictions were combined for analysis purposes. Comparisons of the proportion of hospitals within states using VHI revealed a statistically significant difference between the states (*P* = 0.006). Looking at pairwise comparisons, one could see that WA and Victoria had a larger proportion of ICUs using VHI than Queensland (*P* = 0.04 and *P* = 0.003, respectively), but there was no significant difference between these two states. Victorian ICUs also had significantly greater use of VHI than New South Wales (*P* = 0.018). No other comparisons were statistically significant.

Analyses of the length of use of VHI and the the proportion of physiotherapy treatments in which VHI was used were carried out on the subset of hospitals that were using VHI and no significant differences were observed between the states using VHI.

Table 2. Indications for VHI*

Clinical picture

- Sputum retention (100%)
- Fraction of inspired oxygen (FiO₂) > 0.7 (74%)
- Positive end-expiratory pressure >10 cmH₂O (74%)
- Nitric oxide in use (33%)

Diagnoses

- Respiratory infection (100%)
- Atelectasis (20%)
- Infection risk to staff (8%)

* Figures represent % of facilities that stated this indication.

Specific protocols were followed in 60% of units. Only a third of these protocols were reviewed. It is unknown whether the remaining two-thirds of the facilities have written protocols or base their intervention on one of the protocols reviewed, adjusting implementation on an individual basis. All respondents reported basing their implementation of VHI on their own clinical judgement and experience. Additionally, 40% used published papers, although only half of these could name the papers. Papers cited included Anzueto et al,⁷ Berney and Denehy,⁴ Boussarsar et al,⁸ Eisner et al,⁹ Konrad et al,¹⁰ Maxwell and Ellis¹¹ and Savian et al.⁵

Indications, precautions and contraindications

A range of indications for VHI (Table 2), contraindications (Table 3) and precautions for use (Table 4) in ICU patients were provided.

Modes of application

All but five facilities implemented VHI using both controlled and spontaneous ventilator modes. Of these, one facility used only a spontaneous ventilator mode and the other four used only a controlled ventilator mode.

Table 3. Contraindications for VHI*

Pathological conditions

- Undrained pneumothoraces (100%)
- Bronchopleural fistula (100%)
- Bronchospasm (92%)
- 12% or more facilities stated:
 - Pulmonary bullae/blebs
 - Lung tumours
 - Central airway obstructive lesions
 - Lung abscess
 - Haemoptysis

Physiological parameters: mean (range)

- Cardiovascular instability (20%). Specifically:
 - MAP < 63 mmHg (50–80 mmHg)
 - MAP > 102 mmHg (85–120 mmHg)
 - HR < 56 bpm (35–60 bpm)
 - HR > 123 bpm (100–140 bpm)
 - High-dose inotrope requirement
- Neurological instability (16%). Specifically:
 - ICP > 19 mmHg (15–25 mmHg)
 - CPP < 62 mmHg (60–70 mmHg)
- Respiratory parameters (16%). Specifically:
 - Paw > 33 cmH₂O (30–40 cmH₂O)
 - Increased respiratory rate in agitated patient
- Low platelet level and bleeding (12%)

CPP = cerebral perfusion pressure. HR = heart rate. ICP = intracranial pressure. MAP = mean arterial pressure. Paw = peak airway pressure. VHI = ventilator hyperinflation. * Figures represent % of facilities that stated this contraindication.

Table 4. Precautions in using VHI*

- Acquired brain injury (95%)
- Respiratory parameters (16%)
- Multiple rib fractures/flail segments (12%)

* Figures represent % of facilities that stated this precaution.

Spontaneous mode using pressure support

Not all respondents were able to be specific about increments and limits of application. Of those who responded, most increased pressure support incrementally on both the initial (14/19) and subsequent (11/15) treatments. Increments ranged from 2 to 5 cmH₂O. The majority of respondents limited application based on peak airway pressure (Paw) reached (14/20) rather than volume reached (2/20), but for some it could be either pressure- or volume-limited (4/20). The mean Paw reached was 37 cmH₂O (range, 25–40 cmH₂O). Based on information from the six respondents who answered Question 39, the percentage of tidal volume (Vt) reached ranged from 15% above initial Vt to three times the initial Vt.

Controlled modes using either volume-controlled or pressure-controlled ventilation

Five facilities used VHI in volume-controlled ventilation, three in pressure-controlled ventilation (including one that used airway pressure release ventilation), and 14 used it in either volume- or pressure-controlled ventilation. Not all

respondents were able to be specific about limits of application. The majority said they limited application based on Paw reached (17/22) rather than volume reached (1/22), but for some it could be either pressure- or volume-limited (3/22). The mean Paw reached was 37 cmH₂O (range, 25–40 cmH₂O). Of the six respondents who answered Question 44, the percentage of Vt reached ranged from 20% above initial Vt to three times the initial Vt.

Dosage

There was little difference in the dosage in terms of length of treatment and number of breaths and sets of VHI for the purpose of either sputum clearance or as a respiratory recruitment manoeuvre. There was a wide range of approximate length of treatment sessions across facilities (from 5 to 30 minutes), with many stipulating that every occasion of service would be individualised and clinically driven. There was a mean of five sets of breaths in both groups (range, 2–9), and the same number of breaths per set was used for sputum collection (mean, 7; range, 4–12) as for recruitment (mean, 7; range, 3–12). There was a mean of two daily treatments (range, 1–3) for both groups, with 65% of respondents in each group reporting no limit to the number of daily treatments available.

Positioning was the same for either sputum clearance or recruitment, and when stipulated (84% of cohort) was most commonly side lying with the affected side uppermost (71%). One of the respondents also indicated that they would routinely position with head-down tilt. The remaining six respondents specified that position would always be individualised and clinically driven.

Reassessment

All respondents stated that reassessment after treatment was indicated. The most common outcome measures are summarised in Table 5.

Staff competencies

The majority of physiotherapists (68%) said they undergo training and competency evaluation in the use of VHI, usually as part of the orientation process (Figure 1). A range of training was described, but most facilities included observation of a competent physiotherapist followed by supervised practice. There were only a small number of

SURVEY

facilities (8%) where nursing staff undergo training and competency evaluation in the use of VHI. The details of this training were not provided, but it was thought to be part of the ICU critical care nursing course. Physiotherapists reported that nursing staff had taken over much of the physiotherapy role in these facilities.

Discussion

Our survey showed that, despite little published evidence on the effectiveness of VHI, a substantial number of Australian tertiary ICUs are using VHI as part of normal accepted clinical practice during physiotherapy treatment. We also found that in terms of indications, precautions, contraindications and dosage, there is broad agreement on the application of VHI at these facilities. This may be due to the longstanding use of hyperinflation using MHI and the wide-ranging literature describing the technique. It may also be due in part to the fact that two Victorian facilities were consistently referred to by others as having been responsible for their education and training.

A limitation of our study was the fact that the survey asked participants to recall and estimate VHI parameters. Although we ascertained that only the most senior and experienced physiotherapist was surveyed at each site, there was no way of knowing whether their estimates accurately reflected real clinical practice. Another limitation of our study, with respect to comparisons between states, was that the number of centres was very small in some states, so that apparent differences between the states should be viewed with caution.

Three previous studies exploring the effectiveness of VHI⁴⁻⁶ were fundamentally different from each other in their application and dosage of VHI. Similarly, the results of our survey suggest that the manner in which VHI is applied varies across facilities, although there is consensus on the fact that it is a dynamic technique requiring ongoing titration of ventilation according to clinical response.

Table 5. Treatment outcome measures*

Interventional

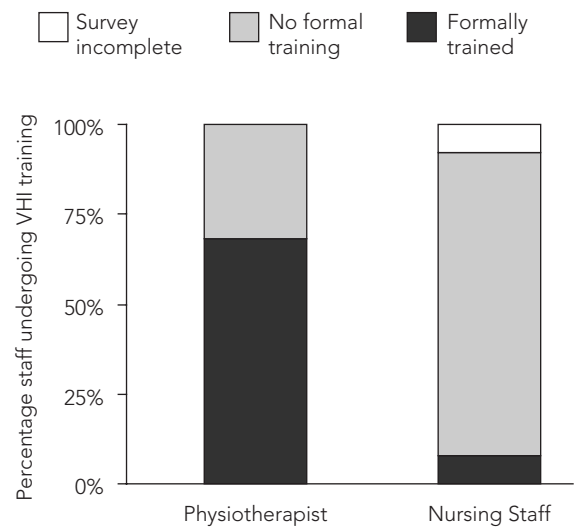
- Sputum volumes (100%)
- Auscultation (96%)
- Arterial blood gas (24%)
- Chest x-ray (20%)

Observational

- Respiratory observations (92%)
- Ventilatory observations (88%). Specifically:
 - Lung compliance (32%)

* Figures represent % of facilities that stated this outcome measure.

Figure 1. Proportion of staff undergoing VHI training



VHI = ventilator hyperinflation.

Dynamic lung function in terms of P_{aw} and/or ventilation volume was always monitored during treatment, and sputum volumes, respiratory and ventilatory observations (including re-auscultation) were reassessed at the conclusion of treatment.

There are potential advantages of VHI over MHI. The most important of these is that, unlike MHI, VHI does not require ventilator circuit disconnection during use. Patients who will not tolerate a circuit disconnection in order to apply or remove the MHI bag can not be hyperinflated using MHI. VHI allows positive end-expiratory pressure levels to be maintained, and may prevent infection transmission to both patient and attending staff associated with circuit disconnection. This may be particularly relevant with the current H1N1 influenza pandemic. There are also direct cost-saving implications, as two people are required to administer routine physiotherapy using MHI, while VHI requires only one person. There is also the potential for indirect cost-saving in terms of scheduling, in that the need to coordinate physiotherapy treatment time with nursing interventions may be removed, allowing physiotherapists to plan their day more effectively.

Conclusion

Physiotherapeutic intervention in the ICU is based on clinical reasoning following thorough systematic assessment. It continues to be an integral component of the supportive management of acute patients in Australian ICUs. VHI looks to be a promising new additional technique that physio-

SURVEY

therapists can use to achieve optimal patient outcomes in some patient groups. Our survey provided information on the current nature and extent of VHI use by physiotherapists in Australian tertiary ICUs. Participation in this research allowed physiotherapists to share their clinical experiences and contribute to education of their peers. Published data will now enable them to compare and evaluate their own practice with that of other Australian facilities, as well as providing a basis for developing standardised evidence-based VHI protocols for both spontaneous and controlled ventilation modes, thus broadening the range of evidence-based treatment options available.

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(Appendix overleaf)

SURVEY

Appendix. Physiotherapist survey

BASELINE DATA

Hospital _____

Telephone number () _____

Senior ICU physiotherapist _____

Telephone number () _____

Appointment date _____

WA local time _____

VHI QUESTIONNAIRE DATA

General

- | | | | |
|---|---|---|--------------|
| 1. Do you utilise VHI in the management of respiratory dysfunction in the intensive care unit setting at your facility? | Y | N | |
| 2. When did you begin utilising the procedure? | | | (Year) _____ |
| 3. Do you follow a specific protocol? | Y | N | |
| 4. If yes in Q3, where was this protocol developed? | | | |
| 5. Do you base the implementation of VHI on published papers? | Y | N | |
| 6. If yes in Q4, which? _____ | | | |
| 7. Do you base the implementation of VHI on your clinical judgement or experience? | Y | N | |
| 8. Do you routinely use VHI with all treatments? | Y | N | |
| 9. If no in Q8, estimate the percentage of treatments undertaken that utilise VHI _____ | | | |
- The following questions deal with your indications for using VHI
- | | | | |
|--|---|---|--|
| 10. Do you utilise VHI in patients requiring high (> 0.7) FiO ₂ ? | Y | N | |
| 11. Do you utilise VHI in patients requiring high (> 10) PEEP? | Y | N | |
| 12. Do you utilise VHI in patients requiring nitric oxide ventilation? | Y | N | |
| 13. Do you utilise VHI in patients with respiratory infection? | Y | N | |
| 14. Do you utilise VHI for facilitating sputum collection? | Y | N | |
| 15. Do you utilise VHI as a recruitment manoeuvre? | Y | N | |
| 16. Can you describe any other indications for the use of VHI? | Y | N | |
| 17. If yes for Q16, please describe these _____ | | | |

The following questions deal with your contraindications for using VHI

- | | | | | |
|--|-----|---|---|--|
| 18. What range of MAP contraindicates the use of VHI? | MAP | < | > | |
| 19. What range of HR contraindicates the use of VHI? | HR | < | > | |
| 20. What range of ICP contraindicates the use of VHI? | ICP | > | | |
| 21. What range of CPP contraindicates the use of VHI? | CPP | | < | |
| 22. What is the peak inspiratory pressure that contraindicates the use of VHI? | | | > | |
| 23. Do you consider undrained pneumothorax as a contraindication to VHI? | | Y | N | |
| 24. Do you consider a bronchopleural fistula as a contraindication to VHI? | | Y | N | |
| 25. Do you consider bronchospasm as a contraindication to VHI? | | Y | N | |
| 26. Can you describe any other contraindications for the use of VHI? | | Y | N | |
| 27. If yes for Q26, please describe these _____ | | | | |

The following questions deal with your precautions for using VHI

- | | | | |
|---|---|---|--|
| 28. Do you consider cardiovascular instability as a precaution to implementing VHI? | Y | N | |
| 29. Do you consider the diagnosis of acquired brain injury as a precaution to implementing VHI? | Y | N | |
| 30. Do you consider recent lung surgery as a precaution to implementing VHI? | Y | N | |
| 31. Can you describe any other precautions for the use of VHI? | Y | N | |
| 32. If yes for Q31, please describe these _____ | | | |
| 33. Do you use VHI in | | | |
| a. controlled modes | Y | N | |
| b. spontaneous modes | Y | N | |
| c. both | Y | N | |

(Appendix continues on following page)

SURVEY

Appendix. Physiotherapist survey (continued from previous page)

The following questions deal with the application of VHI and pressure support

- | | | |
|--|-------|--------------------|
| 34. Do you gradually increase the pressure support on initial treatment? | Y | N |
| 35. If yes in Q34, what are your increments? | _____ | cmH ₂ O |
| 36. On subsequent treatments do you still increase the PS incrementally? | Y | N |
| 37. Do you limit the application by peak pressure or volume reached? | PP | V |
| 38. If PP in Q37, what is your peak pressure reached? | _____ | |
| 39. If volume in Q37, what is the percentage of Vt reached? | _____ | %Vt |

The following questions deal with control modes of ventilation

- | | | |
|---|-------|-----|
| 40. Do you apply VHI in control modes of ventilation? | Y | N |
| 41. If so, which modes do you use it in? | VC | PC |
| 42. If the patient is in a control mode, do you limit by peak pressure or volume? | PP | V |
| 43. If PP in Q42, what is your peak pressure reached? | _____ | |
| 44. If V in Q42, what is the percentage of Vt reached? | _____ | %Vt |

The following questions deal with the dosage of your VHI applications

For sputum clearance:

- | | | |
|--|-------------|------------|
| 45. When you use VHI, how long do you apply it for in one treatment session? | _____ | |
| 46. How many repetitions do you routinely apply in one treatment session? In other words, how many breaths per set, and how many sets? | _____ b/set | _____ sets |
| 47. How many treatments are routinely applied per day, and is there a limit? | _____ | Y N |
| 48. Is there a patient position routinely used when utilising VHI? | Y | N |
| 49. If so, what is the preferred position? | | |

The following questions deal with the dosage of your VHI applications

For recruitment:

- | | | |
|--|-------------|------------|
| 50. When you use VHI, how long do you apply it for in one treatment session? | _____ | |
| 51. How many repetitions do you routinely apply in one treatment session? In other words, how many breaths per set, and how many sets? | _____ b/set | _____ sets |
| 52. How many treatments are applied per day, and is there a limit? | _____ | Y N |
| 53. Is there a patient position routinely used when utilising VHI? | Y | N |
| 54. If so, what is the preferred position? | | |

The following questions deal with patient re-assessment

- | | | | | |
|---|---------------|-----------------|-----------------|-----------------|
| 55. How do you evaluate the success of the treatment? | sputum volume | re-auscultation | respiratory obs | ventilatory obs |
| 56. Other? | | | | |

The final questions deal with staff competency in the VHI technique

- | | | |
|--|---|---|
| 57. Do physiotherapy staff complete training or competency evaluation in the use of VHI? | Y | N |
| 58. Do nursing staff complete training or competency evaluation in the use of VHI? | Y | N |
| 59. Please describe training or competency evaluation | | |

Thank you for undertaking this questionnaire.

CPP = cerebral perfusion pressure. FiO₂ = fraction of inspired oxygen. HR = heart rate. ICP = intracranial pressure. ICU = intensive care unit. MAP = mean arterial pressure. obs = observation. PC = pressure-controlled. PEEP = positive end-expiratory pressure. PP = peak pressure. PS = pressure support. VC = volume-controlled. VHI = ventilator hyperinflation. Vt = tidal volume. WA = Western Australia.