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The safety of mobilisation and its effect on haemodynamic and respiratory status of intensive care patients

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This study investigated the safety of mobilising acutely ill in-patients, in particular the effect of mobilisation on their haemodynamic and respiratory parameters. Thirty one patients in an intensive care unit (ICU) deemed suitable for mobilisation, based on a comprehensive screening process, received 69 mobilisation treatments in total. These treatments most often included sitting on the edge of the bed and standing. Outcome measures including heart rate, systolic and diastolic blood pressure, and percutaneous saturation of oxygen, were measured prior to, during and after mobilisation. Additionally, any deterioration in clinical status, and intervention required for it, was noted. On the majority of occasions (91.3%), pre-treatment data from patients indicated marginal cardiac and/or respiratory reserve. During mobilisation, significant increases were seen in heart rate and blood pressure, while percutaneous oxygen saturation decreased (not significantly). These changes were generally of small magnitude and did not require any specific intervention. On three of the 69 occasions of mobilisation (4.3%), clinical status deteriorated, requiring intervention. For all three patients involved, this was a fall in oxygen saturation, requiring a temporary increase in the inspired fraction of oxygen to stabilise respiratory status. Although mobilisation resulted in significant increases in heart rate and blood pressure and a non-significant fall in percutaneous oxygen saturation, the ICU patients in this study deemed suitable for mobilisation were able to be safely mobilised.

INTRODUCTION

The physiotherapy management of acutely ill patients who are in an intensive care unit (ICU) often incorporates some form of mobilisation. The aims of mobilisation for these patients include increasing lung volumes, improving ventilation/perfusion matching, providing a gravitational stimulus to restore normal fluid distribution in the body, reducing the effects of immobility, and maintaining or improving function and fitness (Bishop, 1996; Dean, 1994; Dean and Ross, 1992a, 1992b; Stiller and Phillips, 2003). Although mobilisation is deemed an

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essential part of the physiotherapy management of acutely ill in-patients, a literature search (of Medline and CINAHL databases) revealed that there is no published clinical research assessing the overall safety of mobilising these patients, nor the effect of mobilisation on haemodynamic and respiratory status. This is an important omission as there is the potential for adverse side effects, especially given the borderline cardiorespiratory function of acutely ill patients. Thus, the aim of this pilot study was to document the safety of mobilisation for acutely ill patients in ICU, in particular the haemodynamic and respiratory responses and the occurrence of any adverse side effects during mobilisation.

METHOD

A prospective study was done over three separate two week periods at the Royal Adelaide Hospital (RAH) ICU and included all patients where mobilisation formed part of the patient's physiotherapy management. These distinct time periods were selected to ensure that a wider selection of patients was included in the study sample than would have been the case if one continuous time period was used. For the purposes of this study, mobilisation was defined as moving from lying to sitting on the edge of the bed, sitting to standing, a standing transfer from the edge of the bed to a chair, or walking. Patients undergoing passive forms of mobilisation, such as positioning upright in bed and mechanical transfers from bed to chair were not studied. The mobilisation task selected was based on the patient's general clinical status and ability. Prior to mobilising any patient, a comprehensive range of factors including medical background, cardiovascular reserve, respiratory reserve and other relevant factors, were taken into consideration to assess whether mobilisation was safe to proceed. This screening process is based on that described by Stiller and Phillips (2003) and is summarised in flow chart format in Figure 1.

Background pre-treatment data were recorded, including descriptive information (e.g., primary diagnosis, major past medical history, days post-admission to ICU, intubation/ventilation status), haematological data (e.g., haemoglobin, platelet count, white cell count), body temperature and weight. In addition, for those patients with an arterial line, the ratio of partial pressure of oxygen in arterial blood to the inspired fraction of oxygen (PaO_2/FIO_2 ratio) was calculated from the most recent arterial blood gas (ABG) as an indication of oxygenation and respiratory reserve (see Table 1).

For the purposes of this study, outcome measures were selected that were easily accessible in a clinical setting. Heart rate (HR) was recorded from the electrocardiograph (ECG) monitor, after ensuring that a satisfactory tracing was present. In addition to recording the absolute value of HR, HR was also expressed as a percentage of the age predicted maximum HR (where the age predicted maximum HR equals 220 minus age, in years) to give an indication of cardiac reserve (Franklin, Whaley, and Howley, 2000; McArdle, Katch, and Katch, 1996; Stiller and Phillips, 2003). The cardiac rhythm was observed on the ECG tracing and any arrhythmias documented. Systolic and diastolic blood pressure (BP) were recorded from an invasive arterial line or, for those patients without an arterial line, from an oscillometric sphygmomanometer. Arterial lines were calibrated on a daily basis according to the RAH ICU protocol. Before invasive BP measurements were recorded it was ensured that a satisfactory tracing was obtained. Percutaneous oxygen saturation (SpO_2) was recorded using a pulse oximeter with a finger or ear probe, after ensuring that a satisfactory tracing was established and that the HR on the oximeter was similar to that seen on the ECG. In addition to these objective parameters, patient appearance was documented and the following noted: conscious state, respiratory pattern, pallor, flushing, sweating, clamminess, cyanosis, visible or patient reported signs of pain, discomfort or fatigue. Any deterioration in the patient's condition during the mobilisation treatment was

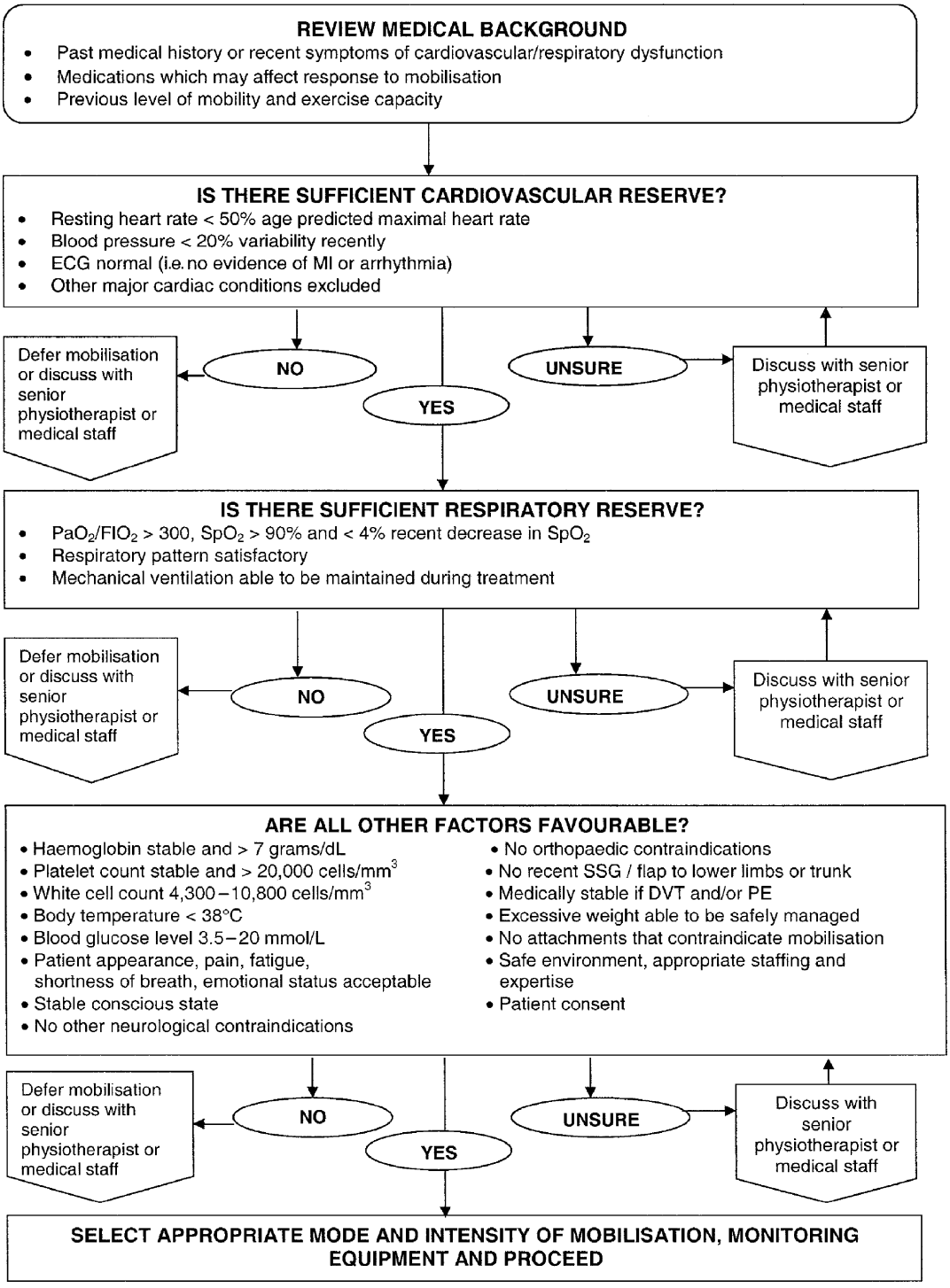

Fig. 1 Overview of safety issues prior to mobilizing acutely ill in-patients (from Stiller and Phillips, 2003).

Table 1
Background data for the 31 patients

Sex – *n* (%)	
Male	18 (58.1%)
Female	13 (41.9%)
Age (years)	
Mean ± SD	57 ± 15
Range	20–81
Primary diagnosis – *n* (%)	
Medical	15 (48.4%)
Surgical	12 (38.7%)
Trauma	4 (12.9%)
Past medical history – *n* (%)	
Nil relevant	12 (38.7%)
Hypertension	8 (25.8%)
Obesity	4 (12.9%)
Chronic obstructive pulmonary disease	4 (12.9%)
Ischaemic heart disease	3 (9.7%)
Symptoms pre-treatment *n* (%)	
Nil	24 (77.4%)
Shortness of breath	6 (19.4%)
Restless	1 (3.2%)
Previous mobility *n* (%)	
Independent	31 (100%)
Days post-admission to ICU	
Mean ± SD	29 ± 19.6
Range	1–71
Intubation and ventilation status *n* (%)	
Not intubated, spontaneously ventilating	18 (58.1%)
Tracheostomy, spontaneously ventilating	6 (19.4%)
Tracheostomy, assisted ventilation	7 (22.6%)
Haemoglobin (g/dL)	
Mean ± SD	9.1 ± 1.6
Range	7.0–15.8
Platelet count (cells/mm^3)	
Mean ± SD	301 ± 170
Range	42–742
White cell count (cells/mm^3)	
Mean ± SD	10,500 ± 3,600
Range	4,400–20,100
Body temperature(° Celsius)	
Mean ± SD	37.2 ± 0.5
Range	36.0–38.2
Blood glucose (mmol/L)	
Mean ± SD	7.3 ± 2.5
Range	4.0–13.6
Weight (kg)	
Mean ± SD	83 ± 34
Range	35–160
Pre-treatment PaO_2/FIO_2 ratio (n = 65)	
Mean ± SD	263 ± 112
Range	124–587
100–200: n (%)	19 (29.2%)
201–300: n (%)	27 (41.5%)
>300: n (%)	19 (29.2%)
Pre-treatment heart rate (n = 69)	
Mean ± SD (bpm)	94.1 ± 14.5
Range (bpm)	69–133
<50% age predicted maximum: n (%)	14 (20.3%)
50 – 70% age predicted maximum: n (%)	47 (68.1%)
71 – 80% age predicted maximum: n (%)	7 (10.1%)
>80% age predicted maximum: n (%)	1 (1.4%)

recorded and any intervention required in its management was noted. These outcome measures were recorded during a baseline period just prior to the mobilisation treatment, during each mobility task (within the first 30 seconds of completion of the task), and within one minute of completion of the entire mobilisation treatment when the patient had been returned to a resting position.

Interval data from the different time periods were compared using the repeated measures analysis of variance test. When a significant time effect was found, paired t tests were used to identify which time periods were significantly different. Probability values of less than 0.05 were considered significant.

RESULTS

A total of 160 patients were in the RAH ICU during the study period, with 31 patients (19.3%) receiving mobilisation as part of their physiotherapy management. The 160 patients received a total of 425 physiotherapy assessments/treatments over the study period, with 69 (16.2%) of these treatments including mobilisation. There were 129 patients who were excluded from the study as they did not receive mobilisation as part of their physiotherapy management. There were a variety of reasons for exclusion such as reduced conscious state, unstable cardiovascular and/or respiratory status, or other precluding factors (e.g., spinal or pelvic fracture; see Figure 1).

Table 1 provides descriptive information and background biochemical and haematological data for the 31 patients included in the study. As can be seen in this table, many of the patients included in the study had limited

cardiac reserve at rest, as indicated by the pre-treatment HR being more than 50 per cent of the age predicted maximum on 55 of the 69 occasions (79.7%) of mobilisation (Stiller and Phillips, 2003; see Figure 1). Marginal respiratory reserve at rest was also evident for some patients, in that the pre-treatment PaO_2/FIO_2 ratio was less than 300 on 46 of 65 occasions (70.7%) in patients with available ABGs (Stiller and Phillips, 2003, see Figure 1). In total, 63 of the 69 mobilisation treatments (91.3%) were performed with patients who had marginal cardiac and/or respiratory reserve at rest (i.e., pre-treatment HR more than 50% age predicted maximum and/or PaO_2/FIO_2 less than 300).

The 69 mobilisation treatments received by the 31 patients involved:

- sitting on the edge of the bed on 39 occasions
- sitting on the edge of the bed and standing on 19 occasions
- sitting on the edge of the bed and standing transfer to a chair on 10 occasions and
- sitting on the edge of the bed, standing and walking on one occasion.

For the purposes of presenting the results (see Table 2 and Figures 2, 3, and 4), the first mobility task refers to the first activity during the mobilisation treatment (in all cases this was sitting on the edge of the bed). For those patients who progressed beyond sitting on the edge of the bed, the second mobility task refers to the second activity during mobilisation (i.e., standing or standing transfer). As only one patient progressed beyond sitting on the edge of the bed and standing (i.e., to walking), data from the walking component of the mobilisation treatment were not analysed.

Figures 2 to 4 show the mean (SD) values for HR, BP and SpO_2 over the 69 occasions of mobilisation at the different time intervals. A significant change was seen over time for HR (absolute and percentage age predicted maximum HR) and for systolic and diastolic BP ($p < 0.001$). Using paired t tests, HR (absolute and percentage age predicted maximum HR) significantly increased from pre-treatment to the first mobility task ($p < 0.001$). A further significant increase was seen from the first to the second mobility task ($p < 0.001$). Post-treatment, HR was still significantly increased from the pre-treatment level ($p < 0.001$). Similar changes

Table 2
Changes in haemodynamic and respiratory data during the 69 occasions of mobilisation for the 31 patients

	Pre-treatment to first mobility task	First to second mobility task	Pre-treatment to post-treatment
Heart rate	$n = 69$	$n = 28$	$n = 69$
Fall	12 (17.4%)	6 (21.4%)	13 (18.8%)
No change	4 (5.8%)	0	4 (5.8%)
Increase	53 (76.8%)	22 (78.6%)	52 (75.4%)
Systolic BP	$n = 61$	$n = 22$	$n = 63$
Fall $\leq$ 20 mmHg	1 (1.6%)	3 (13.6%)	19 (30.2%)
Fall>20 mmHg	8 (13.1%)	5 (22.7%)	1 (1.6%)
No change	0	4 (18.2%)	4 (6.3%)
Increase	52 (85.2%)	10 (45.5%)	39 (61.9%)
Diastolic BP	$n = 61$	$n = 22$	$n = 63$
Fall $\leq$ 10 mmHg	4 (6.6%)	8 (36.4%)	10 (15.9%)
Fall>10 mmHg	0	2 (9.1%)	3 (4.8%)
No change	2 (3.3%)	4 (18.2%)	5 (7.9%)
Increase	55 (90.2%)	8 (36.4%)	45 (71.4%)
SpO_2	$n = 69$	$n = 26$	$n = 69$
Fall < 4%	24 (34.8%)	5 (19.2%)	17 (24.6%)
Fall $\geq$ 4%	10 (14.5%)	3 (11.5%)	7 (10.1%)
No change	20 (29.0%)	7 (26.9%)	19 (27.5%)
Increase	15 (21.7%)	11 (42.3%)	26 (37.7%)

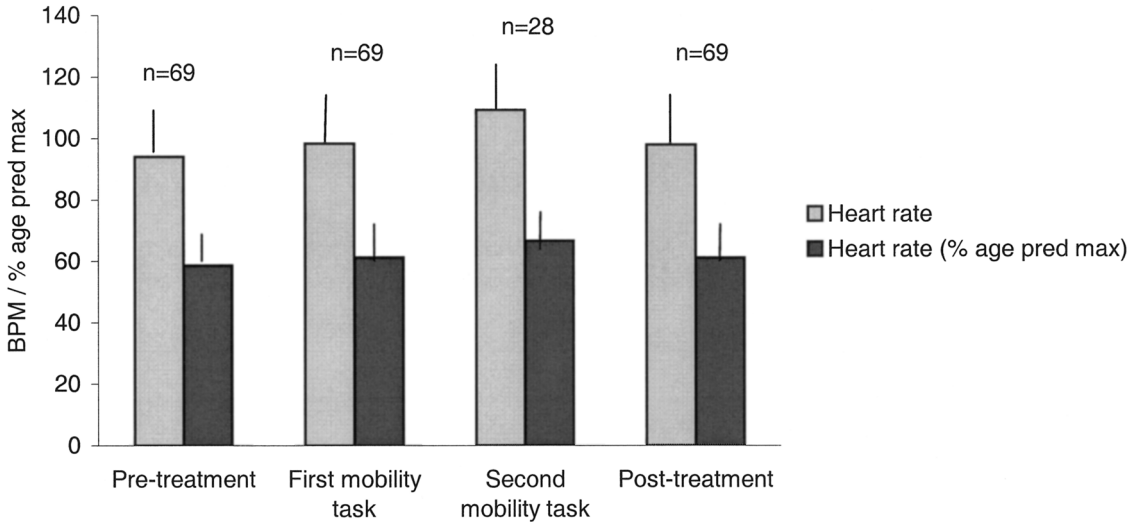

Fig. 2 Heart rate response to mobilisation (means, error bars represent SD).

were seen for systolic and diastolic BP, except that BP during the second mobility task was not significantly different from the first mobility task. Although the changes seen in HR and BP over time were statistically significant, the magnitude of these changes was generally small in terms of absolute and relative values, with most values changing by approximately 10 per cent or

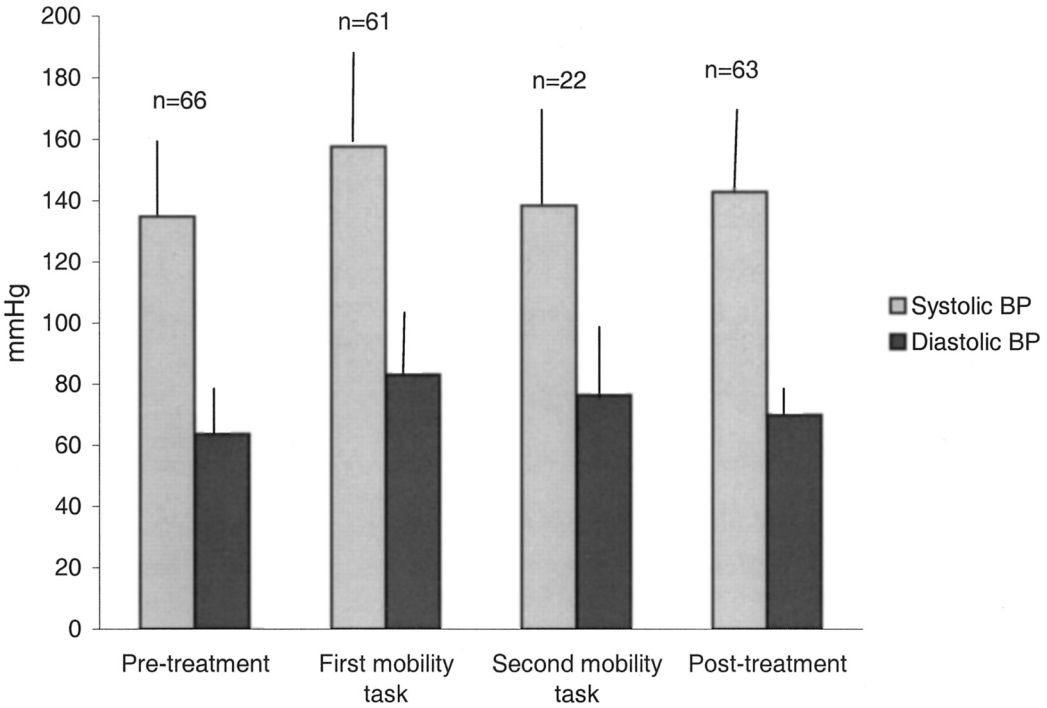

Fig. 3 Blood pressure response to mobilisation (means, error bars represent SD).

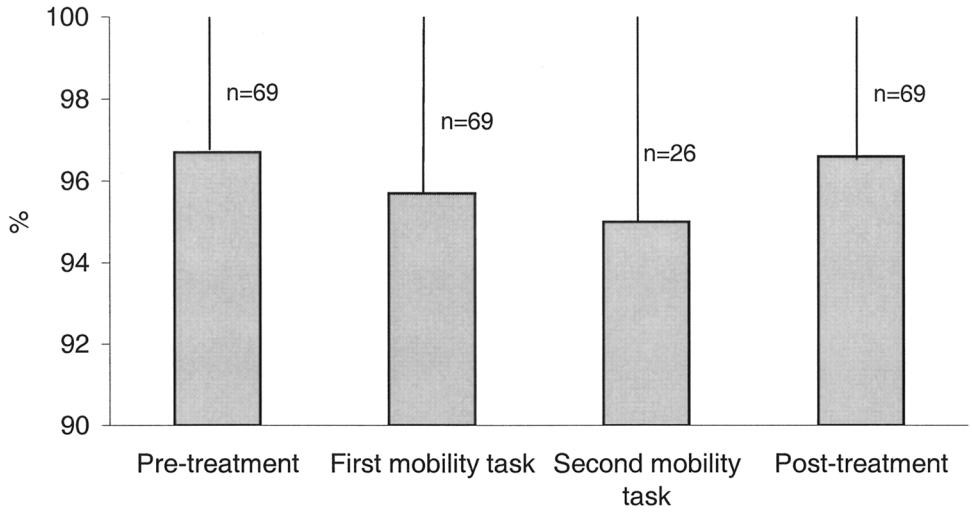

Fig. 4 Percutaneous saturation response to mobilisation (means, error bars represent SD).

less. A fall in SpO_2 was seen during mobilisation, but this was not sufficient to achieve statistical significance ($p = 0.44$).

Table 2 provides the distribution of responses seen during mobilisation. Although the majority of patients showed the expected response in HR and BP (i.e., an increase during mobilisation), there were a number of patients where HR and BP fell during mobilisation.

The most common change in patient appearance seen during the mobilisation treatment was an alteration in respiratory pattern (e.g., increased respiratory rate and/or increased use of accessory muscles of respiration), which was seen on 10 occasions (14.5%). On two of the 69 occasions of mobilisation (2.9%), patients reported dizziness during the mobilisation treatment, but this was not accompanied by orthostatic hypotension, nor did it limit mobilisation or require any direct medical intervention. Cardiac arrhythmias were noted pre-treatment on eight occasions (11.6%)—four cases of atrial fibrillation and four cases of occasional premature ventricular contractions. In each instance the cardiac arrhythmia had been present for some time and did not require medication, nor did it affect haemodynamic stability. Therefore mobilisation was deemed safe to proceed (see Figure 1). No change in the severity or frequency of the arrhythmias was noted during mobilisation.

On three of the 69 occasions of mobilisation (4.3%), a deterioration in a patient's condition occurred that required specific intervention. The salient features of the three patients who deteriorated during mobilisation are provided in Table 3. In all three cases, the deterioration was a fall in SpO_2. In One case (patient 1 in Table 3), the desaturation occurred during the first occasion on which mobilisation was attempted. For the other two patients, the destauration occurred on the second occasion of mobilisation. For two of the patients the desaturation occurred while sitting on the edge of the bed (patients 2 and 3, Table 3) and the other patient (patient 1) desaturated when proceeding from sitting to standing. In each case the patient required a temporary increase in FIO_2, which resulted in an improvement in SpO_2 and did not necessitate further intervention or termination of the mobilisation treatment. To determine if there were any features that were able to predict patients likely to deteriorate during mobilisation, the data from the three patients whose condition deteriorated during mobilisation were further reviewed. All three patients (see Table 3) had pre-treatment HRs that were more than 60 per cent of their age predicted

Table 3
Characteristics of the three patients who deteriorated during mobilisation

	Patient 1	Patient 2	Patient 3
Sex/age (years)	F/70	F/62	M/74
Primary diagnosis	Exacerbation COPD	Post-operative respiratory failure	Respiratory failure
Past medical history	COPD, malnutrition	Nil	CLL
Weight (kg)	35	40	75
Symptoms	SOB pre-treatment	Nil	Nil
Days post-admission	1	56	23
Intubation status	Not intubated	Tracheostomy	Tracheostomy
Ventilation status	Nasal speculae	Pressure support	Pressure support
Pre-treatment PaO_2/FIO_2	232	145	291
Pre-treatment HR (% age pred max)	66.0	60.8	66.4
Highest HR during mobilisation (% age pred max)	73.3	55.1	69.2
Pre-treatment BP (mmHg)	145/65	95/51	146/45
BP during mobilisation	150/64	189/100	158/64
Pre-treatment SpO_2	87	92	97
Lowest SpO_2 during mobilisation	78	88	87

maximum, suggesting particularly limited cardiac reserve at rest (see Figure 1). However, 13 other patients had pre-treatment HRs higher than 60 per cent of their age predicted maximum and did not demonstrate any adverse effects during mobilisation. Only one of the three patients (patient 2) had a pre-treatment BP that would be considered abnormal. However, her BP had been stable at this low level, without inotropic assistance, for several days and she required no treatment for the hypotension, therefore mobilisation was deemed safe to proceed (see Figure 1). As can be seen from Table 3, this patient showed a marked increase in BP during mobilisation. However, this measurement may be inaccurate due to the position of the arterial line. As far as oxygenation is concerned, patient 2 had particularly marginal respiratory reserve pre-treatment (i.e., a PaO_2/FIO_2 ratio of 145; see Figure 1). However, six other patients had a ratio less than 145 and did not deteriorate during mobilisaton. As far as pre-treatment SpO_2 is concerned, there were only two of the 69 occasions of mobilisation when this was less than 90 per cent, one of which was for patient 1 who then went on to desaturate during mobilisation. Therefore, while a pre-treatment SpO_2 of less than 90 per cent seemed to be predictive of desaturation during mobilisation, it is not possible to draw firm conclusions from this small patient sample. No other factors were able to be identified that could predict those patients who deteriorated during mobilisation. Despite the marginal cardiovascular and/or respiratory reserve of these three patients (see Figure 1), mobilisation was undertaken as its perceived benefits were thought to outweigh the potential risks.

DISCUSSION

This study found that mobilisation was associated with significant increases in HR, systolic and diastolic BP, and a decrease in SpO_2. Although the changes were statistically significant for HR and BP, the magnitude of the changes was of minor clinical importance. There were only three episodes of major clinical importance (4.3%) when specific intervention was required during mobilisation to stabilise haemodynamic and/or respiratory status, with all three patients responding quickly to minimal intervention. Thus, mobilisation was well tolerated in those patients deemed suitable for mobilisation, even though their pre-treatment data suggested limited cardiac and/or respiratory reserve (see Figure 1).

Although a low incidence of problems during mobilisation was found in this study, it is imperative to stress that a comprehensive screening process (Stiller and Phillips, 2003) was used to select suitable patients for mobilisation. Additionally, appropriate precautions were taken prior to, during and after mobilisation. The screening process presented in flow chart format in Figure 1 is a simplified version of the guidelines published by Stiller and Phillips (2003). In the current study, despite the majority of patients showing limited pre-treatment cardiac and/or respiratory reserve according to the flow chart (see Figure 1), the perceived benefits of mobilisation were deemed to outweigh the perceived risks. As is explained more fully in the complete set of guidelines (Stiller and Phillips, 2003), the parameters shown in Figure 1 are not intended to be contraindications to mobilisation or interpreted in isolation, but instead should be used in conjunction with sound clinical judgement. Experienced clinicians are often able to discern which patients will tolerate mobilisation despite marginal cardiac and/or respiratory reserve at rest. This relies on the ability of the experienced clinician to take into account the more objective parameters (see Figure 1) and also to observe and interpret more subjective factors, such as patient appearance, conscious state and level of pain and fatigue. For example, as noted by Stiller and Phillips (2003), patient appearance (e.g., facial expression, cyanosis, pallor, flush, clamminess, sweatiness, anxiety) can provide the discerning clinician with essential information regarding how well a patient will tolerate mobilisation—information that may not be evident with other measures. With experience, clinicians can synthesise all the information available and discriminate between patients who will or will not tolerate active mobilisation, despite marginal reserve. The low incidence of problems in this study suggests that this screening process, which includes clinical judgment, can assist in the identification of patients who will tolerate mobilisation. Additionally, this overview of safety issues prior to commencing mobilisation was able to highlight those patients likely to have potential problems and help identify which systems were likely to be challenged during mobilisation.

The haemodynamic responses that most patients showed during mobilisation were as anticipated, in that there was a progressive increase in HR during mobilisation and a return to near baseline levels at the completion of the mobilisation treatment (Franklin et al, 2000; McArdle et al, 1996; Selwyn and Braunwald, 2001). Blood pressure (diastolic and systolic) showed a similar response to HR. However it was evident that the increases in BP seen for patients with invasive arterial lines often seemed excessive. This is likely to reflect the inaccuracy of invasive BP measurement when the arterial line is moved from the position in which it has been calibrated. The haemodynamic responses seen during mobilisation in this study were similar to those reported during respiratory physiotherapy treatment (Cohen, Horiuchi, Kemper, and Weissman, 1996; Klein et al, 1988; Weissman et al, 1984) and other routine ICU activities (e.g, movement of the body and limbs, physical examination; Weissman et al, 1984).

It was anticipated that oxygenation of these acutely ill patients would improve during mobilisation, due to the expected beneficial effects of the upright position on lung volumes and ventilation/perfusion distribution (Dean, 1985; Dean and Ross, 1992a, 1992b; Ross and Dean, 1992; Wong, 1999). Instead, in this sample of acutely ill patients, SpO_2 decreased during the first mobility task and showed a further decrease during the second mobility task. This fall in SpO_2 most likely reflects that, despite the theoretical benefits, the patients' cardiorespiratory systems could not meet the increased oxygen demand imposed by the mobilisation treatment. However, these decreases did not achieve statistical significance, nor, as a fall in SpO_2 of four per cent or more is usually required to be considered clinically significant (Franklin et al, 2000; see Figure 1), would they be considered clinically significant.

It could be argued that the three patients whose condition deteriorated during mobilisation should not have been mobilised at all based on their pre-treatment data (see Figure 1).

However, for all three patients it was thought that the potential benefits of mobilisation outweighed the potential risks. Furthermore, even though all three patients desaturated during mobilisation, they quickly recovered once FIO_2 was increased, which vindicated the decision to perform mobilisation. Hypothetically, if increasing the FIO_2 had not improved SpO_2, appropriate interventions may have included terminating the mobilisation treatment and, it necessary, increasing the level of ventilatory support. In a similar way that pre-oxygenation prior to suction has been shown to prevent suction induced hypoxaemia (Chulay, 1988; Ciesla, 1996; Mancinelli-Van Atta and Beck, 1992), it is possible that increasing FIO_2 prior to mobilisation may be beneficial for patients with marginal oxygenation.

Further research should be undertaken with similar patient groups to confirm the findings of this study. This may help to identify factors that predict which patients are likely to deteriorate during mobilisation. It may also be helpful in future research to measure oxygenation during mobilisation using parameters obtained from ABGs, such as the PaO_2/FIO_2 ratio, as this takes into account the FIO_2 and thus more accurately reflects oxygenation and the underlying respiratory reserve (Stiller and Phillips, 2003). However, the frequent measurement of ABGs is often impractical in the clinical setting, whereas SpO_2, by virtue of being a non-invasive measurement, provides instantaneous feedback to the clinician. Additionally, this study only measured patients for a short time after the completion of the mobilisation treatment, and longer term effects of mobilisation could be investigated. Although randomised controlled studies would more clearly establish the role of mobilisation in the recovery of acutely ill patients, it may be difficult to withhold mobilisation from an ethical viewpoint.

CONCLUSION

This study found that mobilisation of acutely ill ICU patients resulted in a significant increase in HR and BP, and a fall in SpO_2. Although some changes were statistically significant, the magnitude of the changes was of little clinical importance. There were only three episodes that were deemed of major clinical importance (4.3%), in that specific intervention was required. Although most patients demonstrated marginal cardiac and/or respiratory function pre-treatment, mobilisation was well tolerated in this patient sample. Thus, if appropriate screening procedures and precautions are taken prior to and during mobilisation, acutely ill ICU patients deemed suitable for mobilisation can be safely mobilised without major deterioration in their clinical status.

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