



# HEMODYNAMIC CHANGES WITH MANUAL AND AUTOMATED LATERAL TURNING IN PATIENTS RECEIVING MECHANICAL VENTILATION

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**CNE** 1.0 Hour

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A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Identify hemodynamic changes that occur with manual repositioning.
2. Discuss hemodynamic changes that occur with continuous rotation.
3. Determine if use of manual or automatic turning is safe for medical-surgical patients receiving mechanical ventilation.

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**Background** Lateral turning of critical care patients receiving mechanical ventilation can adversely affect hemodynamic status. **Objective** To study hemodynamic responses to lateral turning. **Method** A time-series design with automated signal processing and ensemble averaging was used to evaluate changes in heart rate, mean arterial pressure, and pulse pressure due to lateral turning in 13 adult medical-surgical critical care patients receiving mechanical ventilation. Patients were randomly assigned to the manual-turn or the automated-turn protocol for up to 7 consecutive days. Heart rate and arterial pressure were measured every 6 seconds for more than 24 hours, and pulse pressure was computed.

**Results** A total of 6 manual-turn patients and 7 automated-turn patients completed the study. Statistically significant changes in heart rate, mean arterial pressure, and pulse pressure occurred with the manual turn. Return of the hemodynamic variables to baseline values required up to 45 minutes in the manual-turn patients (expected recovery time  $\leq$  5 minutes). However, clinically important changes dissipated within 15 minutes of the lateral turn. The steady-state heart rate response on the right side was slightly greater (3 beats per minute) than that on the back ( $P = .003$ ). Automated turning resulted in no clinically important changes in any of the 3 variables.

**Conclusions** In medical-surgical critical care patients receiving mechanical ventilation, manual lateral turning was associated with changes in heart rate, mean arterial pressure, and pulse pressure that persisted up to 45 minutes. (*American Journal of Critical Care*. 2015;24:131-140)

Critically ill patients treated with mechanical ventilation are at high risk for preventable pulmonary complications. A standard of care to reduce complications is lateral turning every 2 hours. Lateral turning of intensive care patients receiving mechanical ventilation can adversely affect hemodynamic status.<sup>1,2</sup> Although the adverse effects are typically transient,<sup>3,4</sup> clinicians may be reluctant to laterally position critically ill patients who are receiving mechanical ventilation.

Clinicians may be reluctant to laterally turn critically ill patients treated with mechanical ventilation.

Positive-pressure ventilation can reduce venous return<sup>5</sup> and cardiac output.<sup>6,7</sup> Lateral turning may augment adverse hemodynamic effects in patients receiving mechanical ventilation. A decrease in blood pressure in the lateral position, compared with the back position, has been reported.<sup>8,9</sup> Gawlinski and Dracup<sup>10</sup> found that blood pressure returned to baseline values within 5 minutes of a turn, suggesting

that lateral turning has a transient effect. Because factors that cause decreased venous return would be maintained throughout the time spent in the lateral position, transient effects on blood pressure suggest that the changes are either responses involved in hemodynamic compensation or responses to the physical act of turning and not to the lateral position per se.

Research on the hemodynamic effects of lateral turning has been limited by the use of discrete measurements (eg,  $\leq 5$  time points in each lateral position) and short study duration. The hemodynamic effects of automated turning have not been systematically evaluated. We conducted a randomized clinical trial as a pilot study to compare the efficacy for preventing and treating pulmonary

complications and the safety of 2 turning interventions (www.ClinicalTrials.gov: NCT00542321): manual turning every 2 hours (standard of care and control group) and continuous automated turning with a kinetic therapy bed (experimental group). As a component of the safety assessment, we examined turning-related hemodynamic responses, defined as changes in heart rate, mean arterial pressure (MAP), and pulse pressure.

## Materials and Methods

A time-series design with automated signal processing and ensemble-averaging was used to measure heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), and MAP every 6 seconds for more than 24 hours. The research protocol was approved by the appropriate institutional review boards at the University of Texas Health Science Center at Houston and the 2 participating hospitals. The 13 eligible adult patients recruited for the study were assessed for hemodynamic response to manual or automated turning.

## Interventions

The manual-turning protocol included a lateral turn of 45° or greater every 2 hours for a duration of 2 hours. Research nurses turned patients to the lateral position, ensuring that the patients' proper body alignment was maintained with the lower leg in extension and the upper leg and upper limbs flexed. Pillows were placed between each patient's thighs, shins, and arms for comfort. Adherence to the protocol was assessed every 10 minutes.

The TriaDyne Proventa bed (ArjoHuntleigh) was used for automated turning. The automated-turning protocol included continuous rotation with lateral rotation to an angle of 40° or greater. Research nurses measured the maximum angle achieved and the direction of turn every hour.

## Study Procedures

General study procedures, including random selection and assignment, have been reported elsewhere.<sup>11</sup> Hemodynamic data were obtained with a

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physiological monitor (HP Component Monitoring System, Philips Medical Systems, or Solar 8000i, GE Healthcare) and an arterial catheter pressure transducer (Edwards Lifesciences, PX600F or PX284). Heart rate and blood pressure data from the HP system were directly transferred via an RS232 serial interface to a laptop computer by using a custom-written software application in the LabView programming environment (National Instruments). Heart rate, SBP, DBP, and MAP were downloaded every second with date and time stamp and were aggregated in sequential 6-second means. For the Solar monitor, BedMaster (version 1.3, Excel Medical Electronics) software was used to communicate with the hospital's Unity Network (General Electric/Marquette) to obtain the data. Pulse pressure was calculated as SBP minus DBP.

In order to account for hydrostatic-pressure effects related to changes in the height of the pressure transducer with continuous rotation, a correction formula for MAP was applied, as reported elsewhere.<sup>12</sup> The height-adjustment correction was not applied to pulse pressure because this variable is the difference between SBP and DBP, 2 quantities that are equally affected by the changes in height. Pulse pressure therefore reflects a difference that is independent of the height of the transducer.

### Data Management and Analysis

SPSS (version 17.0, SPSS Inc) and TIBCO Spotfire S+ (version 8.1, TIBCO Software Inc) software programs were used for data management and analyses. Outliers, defined as data points 3 or more standard deviations from the mean, and missing data were replaced by using linear interpolation.<sup>13</sup> Ensemble averaging,<sup>14</sup> adjusted for autocorrelated data, was used to assess within-subject hemodynamic responses to turning. Heart rate, MAP, and pulse pressure were evaluated for graphical characteristics of increase or decrease with the manual turn and 95% CI overlap with the automated turn; statistical significance; clinical importance; and, in the manual-turn group, recovery time, defined as length of time for the value to return to baseline. A change in heart rate of more than 10 beats per minute, changes in MAP and pulse pressure of 10 mm Hg or greater, and 5 minutes or more for recovery were determined a priori as clinically important changes.<sup>10,15</sup>

For the manual-turn patients, heart rate, MAP, and pulse pressure data were segregated into 4 turn categories: back to left, left to back, back to right, and right to back. Data for each turn category were averaged in 12-second bins (aggregated data) to reduce high autocorrelation in the data,<sup>12</sup> starting 15 minutes before the turn (pretturn period) and ending

45 minutes after the turn (postturn period). The first 5 minutes of the pretturn period was considered the baseline interval. Starting at the end of the baseline interval, data intervals of 5-minutes duration were compared statistically with the baseline interval, moving forward in 1-minute increments to define each subsequent test interval. The mean values of the baseline interval and each test interval were compared by using a generalized least-squares model with a first-order autoregression parameter<sup>16</sup> to account for the correlated nature of the data at each interval. By using the ensemble averages for each variable, a patient's maximum magnitude of change was identified on the basis of statistically significant differences from the pretturn baseline in the postturn data.

Because of the continuous, slow turning for the automated-turn patients, a different approach was used. Heart rate, MAP, and pulse pressure data were segregated into 10° angle bins (aggregated data) that were distinguished by direction of movement so that a picture of the entire 12-minute rotation cycle could be obtained. Bin angles from -10° to 10° were considered the back position. The left position corresponded to angles less than -10° and the right position to angles greater than 10°. The last bin on each side was an "open" bin due to variable maximum angles obtained with the automated bed ( $\pm 30^\circ$  to  $\pm 60^\circ$ ) for a total of 8 angle bins. Because large numbers of turns were available for automated turning, the ensemble average in each angle bin was computed according to a longitudinal mixed-effects model with random intercept for the turns and first-order autoregressive structure.<sup>17</sup>

At the across-subjects level, 2-way analysis of variance was used to compare changes in heart rate, MAP, and pulse pressure between turn groups and back-to-right and back-to-left positions. Mean values were determined for each turn direction (manual-turn group) or angular bin (automated-turn group). In the automated-turn group, angle bins in the back position were combined and then compared separately with angle bins in the left and right positions. The 95% CI of the overall mean was an estimate of the variability.

### Results

The study consisted of 6 patients (46%) randomly assigned to the manual-turn group and 7 patients (54%) randomly assigned to the automated-turn group. Patients' demographic and clinical

Heart rate, blood pressure, and mean arterial pressure were downloaded every second.

**Table 1**  
Patients' demographic and clinical characteristics

Characteristic	Manual turn (n = 6)	Automated turn (n = 7)	<i>p</i> <sup>a</sup>
Age, range (mean [SD]), y	38-77 (54 [13.2])	45-75 (60 [10.7])	.38
Men, No. (%)	3 (50)	4 (57)	.76
Score on Acute Physiology and Chronic Health Evaluation II, range (mean [SD])	18-36 (29 [6.6])	15-29 (24 [5.4])	.19
Requirement of vasopressors, No. of patients (%)	4 (67)	2 (29)	.41
Positive end-expiratory pressure, range (mean [SD]), cm H <sub>2</sub> O	0-12 (5.3 [3.6])	0-12.5 (5.4 [3.0])	.94
Diagnosis or condition, No. (%) of patients			.32
Pneumonia/respiratory failure	3 (50)	2 (29)	
Sepsis/shock	0 (0)	1 (14)	
Neurological	1 (17) <sup>b</sup>	2 (29) <sup>c</sup>	
Cardiopulmonary resuscitation	0 (0)	1 (14)	
Liver failure	1 (17)	0 (0)	
Other	1 (17) <sup>d</sup>	1 (14) <sup>e</sup>	

<sup>a</sup> Independent samples *t* test used for age, score on Acute Physiology and Chronic Health Evaluation II, and positive end-expiratory pressure; Pearson  $\chi^2$  test for use of vasopressors and diagnosis or condition.

<sup>b</sup> Meningitis.

<sup>c</sup> Seizure, West Nile encephalitis.

<sup>d</sup> Overdose.

<sup>e</sup> Suicide attempt with insulin and ingestion of toilet bowl cleaner.

characteristics did not differ significantly between the 2 groups (Table 1). Data collection time varied from 27.1 to 165.2 hours. Heart rate data were collected for all patients, and blood pressure data were collected for the 7 patients (54%) who had an arterial catheter placed for clinical purposes.

Standardized residuals were less than or equal to  $\pm 2$  for all hemodynamic variables, suggesting normal distribution of the data.<sup>18</sup> The length-of-time series data used in the analysis for each patient varied from 16 247 to 99 095 data points, representing a mean of 79.2 (SD, 51.3) hours for the manual-turn and 74.9 (SD, 55.7) hours for the automated-turn group ( $P = .88$ ). Combined outlier and missing values represented 3.4% or less of the data. For the manual-turn group, turning was maintained for 94% of the time patients were on protocol, and mean turn angle was 50° (SD, 5°); for the automated-turn group, these values were 91% and 32° (SD, 3°), respectively. Mean turn angle differed significantly between groups ( $P = .003$ ). Within-subject mean changes in heart rate, MAP, and pulse pressure across all turns for the manual- and automated-turn groups are presented in Figure 1. Postturn recovery time (manual-turn group only) is presented in Table 2.

### Ensemble Averages of the Manual-Turn Group

Manual lateral turning induced changes in heart rate, MAP, and pulse pressure. Figure 2 shows individual turn data and ensemble-averaged data for patient P001 as an example. Graphical displays of the data show hemodynamic responses to turning both in the individual turns (Figure 2, panels A, B,

and C) and ensemble-averaged data (Figure 2, panels D, E, and F). Clinically important changes in heart rate were detected in 2 patients in the left position and in 2 patients in the right position. With the exception of 1 patient in the back-to-left position, all patients showed a prolonged, statistically significant recovery time in heart rate from 9 to 45 or more minutes after turning (Table 2); clinically important changes (heart rate,  $\pm 10$  beats per minute) were transient and dissipated within 15 minutes of the turn. The same was true for MAP and pulse pressure recovery times.

Of the 4 manual-turn patients who had an arterial catheter, 2 had statistically and clinically significant increases in MAP with a change in position that varied from +13 to +22 mm Hg (Figure 1B). Magnitude of change did not differ between back-to-left (+22 mm Hg) and back-to-right (+21 mm Hg) lateral turning. Three patients had prolonged MAP recovery time that varied from 9 to 37 or more minutes (Table 2). A total of 4 patients had statistically significant changes in pulse pressure associated with manual turning: 3 had an increase and 1 had a decrease, but only 1 of the changes was a clinically important change, with the greatest magnitude of +23 mm Hg in the back-to-left position. Three patients had prolonged pulse pressure recovery time of up to 43 minutes (Table 2).

### Ensemble Averages for the Automated-Turn Group

Automated turning induced changes in heart rate, MAP, and pulse pressure (Figures 3A, 3B, and 3C). Among the 7 patients, 3 (43%) had a statistically significant heart rate response to left and right

turning compared with the back position. However, the changes were not clinically important; the maximum response was a change in heart rate of 2 beats per minute compared with the back position. All 3 automated-turn group patients with an arterial catheter had a statistically significant decrease in MAP when turned to the left and right positions compared with the back position; the magnitude of response varied from -4 to -9 mm Hg. With the height-adjusted model, MAP differences were 1 mm Hg or less. Two patients had a statistically significant change in pulse pressure in both the left and right positions compared with the back position. The changes were not clinically important; the maximum response was 5 mm Hg or less (Figure 3C). Because the patients were in constant motion, recovery time could not be calculated.

### Group Comparisons

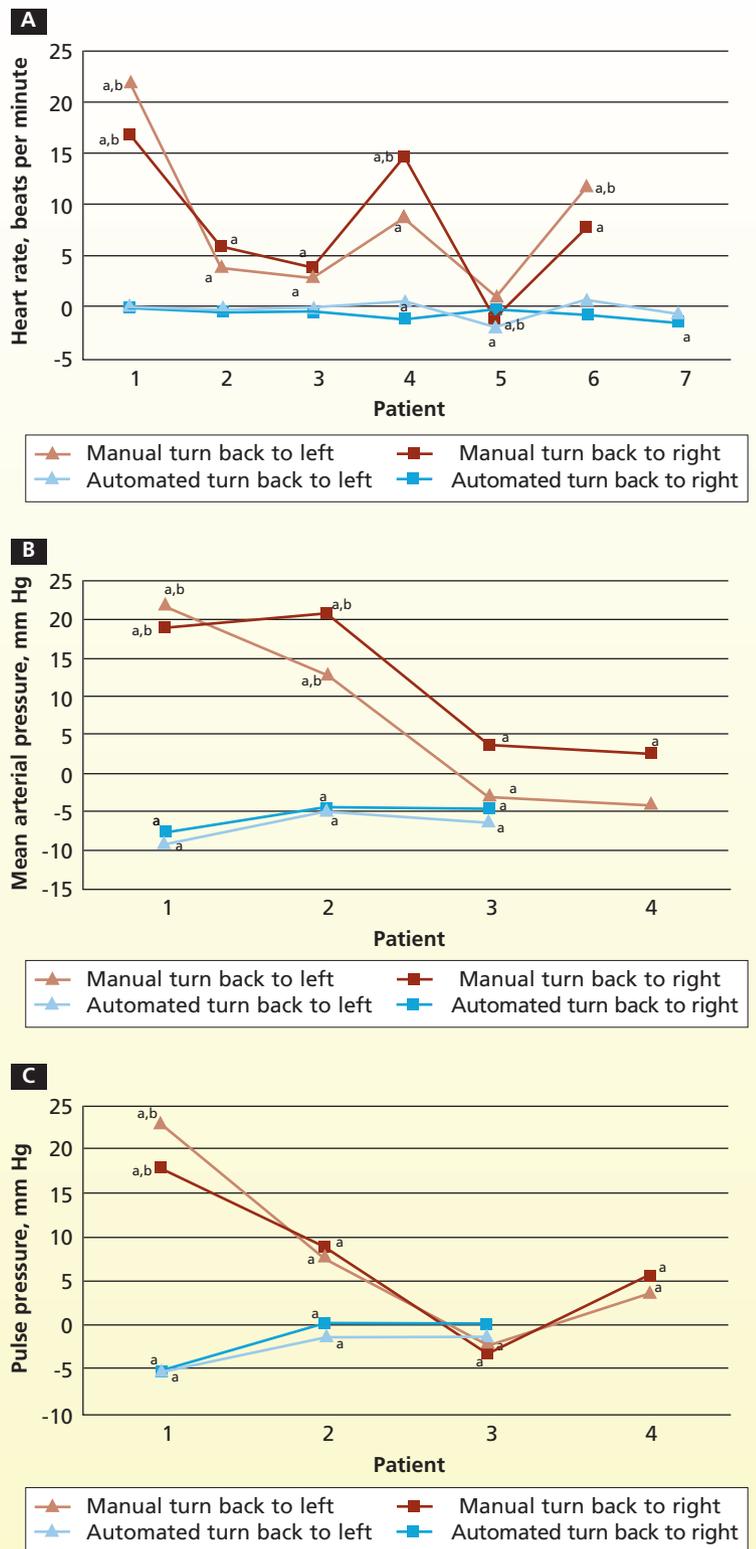
The change in heart rate for the manual-turn group was significantly greater in the right lateral than in the back position ( $P = .003$ ); the mean change of +3 beats per minute was not clinically important. No other within-group differences in position or position by group interaction were significant. Between-group differences in heart rate, MAP, and pulse pressure were not significant.

### Power Computation

Power calculations with  $\alpha = .05$  showed that the study was adequately powered (>89%) to detect within- and between-group clinically important changes in heart rate and MAP and within-group changes in pulse pressure, but not clinically important changes in pulse pressure between turning-intervention groups.

### Discussion

In this study of manual vs automated turning, statistically significant changes occurred in heart rate, MAP, and pulse pressure with manual turning. The heart rate and MAP changes were clinically important in 50% and 25% of patients, respectively, in this small study sample. These findings may reflect the higher mean scores on the Acute Physiology and Chronic Health Evaluation II and the greater percentage of patients with vasopressor support in the manual-turn group, despite random selection and assignment of patients. The times for the hemodynamic parameters to return to baseline values were highly variable: in some patients, heart rate did not recover to baseline within the observation period of 45 minutes after a turn. All patients with an arterial catheter in the automated-turn group



**Figure 1** Summary of within-subject ensemble-averaged mean change in heart rate (A), mean arterial pressure (B) and pulse pressure (C) with lateral turning in the manual-turn group (n=6) and the automated-turn group (n=7). Back position was compared with lateral position (left or right) in both groups. A total of 4 manual-turn and 3 automated-turn patients had an arterial catheter.

<sup>a</sup> Statistically significant,  $P \leq .05$ .

<sup>b</sup> Clinically significant, mean change  $\pm 10$ .

**Table 2**

**Summary of within-subject recovery time for heart rate, mean arterial pressure, and pulse pressure for the manual-turn group (n = 6)**

Patient	Recovery time, range (mean [SD]), min		
	Heart rate	Mean arterial pressure	Pulse pressure
P001	24 <sup>a</sup> to ≥45 <sup>a</sup> (35 <sup>a</sup> [16])	17 <sup>a</sup> to 37 <sup>a</sup> (27 <sup>a</sup> [14])	5 <sup>a</sup> to 10 <sup>a</sup> (8 <sup>a</sup> [4])
P005	9 <sup>a</sup> to 32 <sup>a</sup> (21 <sup>a</sup> [16])	16 <sup>a</sup> to ≥37 (27 <sup>a</sup> [15])	19 <sup>a</sup> to ≥43 <sup>a</sup> (31 <sup>a</sup> [17])
P006	≥44 <sup>a</sup> to ≥45 <sup>a</sup> (45 <sup>a</sup> [1])	9 <sup>a</sup> to 19 <sup>a</sup> (14 <sup>a</sup> [7])	4 to ≥39 <sup>a</sup> (22 <sup>a</sup> [25])
P009	9 <sup>a</sup> to ≥45 <sup>a</sup> (28 <sup>a</sup> [26])	Not applicable (no arterial catheter)	Not applicable (no arterial catheter)
P011	±1 to 16 <sup>a</sup> (8 <sup>a</sup> [11])	±1 to 16 <sup>a</sup> (8 <sup>a</sup> [11])	6 <sup>a</sup> to 13 <sup>a</sup> (10 <sup>a</sup> [5])
P012	34 <sup>a</sup> to ≥38 <sup>a</sup> (36 <sup>a</sup> [3])	Not applicable (no arterial catheter)	Not applicable (no arterial catheter)

<sup>a</sup> Clinically significant: recovery time ≥5 minutes.

had a statistically significant change in MAP and all but 1 had a significant change in pulse pressure in the lateral position. However, less than half of the automated-turn group had a statistically significant change in heart rate, and none of the hemodynamic changes was clinically important. Furthermore, the MAP differences were not statistically significant in the height-adjusted model. Thus, automated turning does not appear to adversely affect hemodynamic status and may be the preferred turning intervention when patients are at risk for unstable hemodynamic status.

The differences in hemodynamic responses we found between manual and automated turning may be due to the angle of turn, which was greater in the manual-turn group. On the basis of the literature, we expected to see a decrease in MAP with lateral turning. Bein et al<sup>2</sup> observed an increased heart rate in the left and right positions and decreased MAP on the right side 15 minutes after a manual turn, whereas in our study, clinically important changes had abated before then in all but 2 patients. Differences in recovery time may be related to different populations of patients, turning protocols, and number of measurements of heart rate and MAP.

Our study differed from that of Bein et al<sup>2</sup> in 4 ways. First, the mean score on the Acute Physiology and Chronic Health

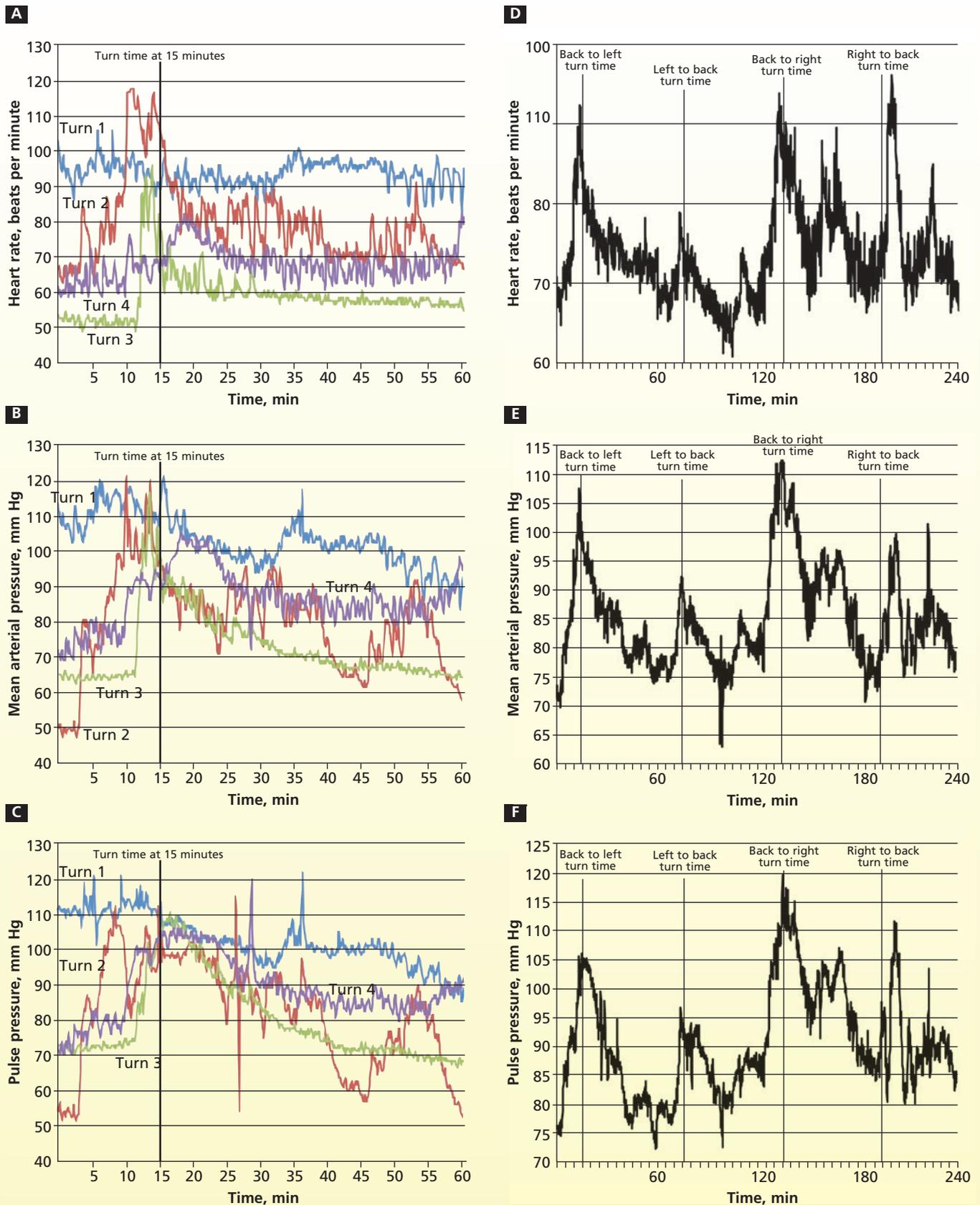
Evaluation II was higher in our patients (29 vs 20). Second, only 46% of our patients were receiving cardiac inotropic medications whereas all of the patients in the study by Bein et al were. Third, patients were turned to mean angles of 50° on our study and 62° in the other study. Fourth, we measured

hemodynamic response to lateral turning continuously, whereas Bein et al obtained 1 measurement after patients had been in the lateral position for 15 minutes. Perhaps, in our study, turn angles were insufficiently steep to reduce venous return and cardiac output. Patients were laterally rotated to an angle of 62° in those studies<sup>8,19</sup> in which differences between left and right positions were found. In our study, marked increases in heart rate and MAP with manual turns were reproducible and transient, suggesting that the physical turning maneuver produced an autonomic nervous system response that resolved with time in the lateral position.

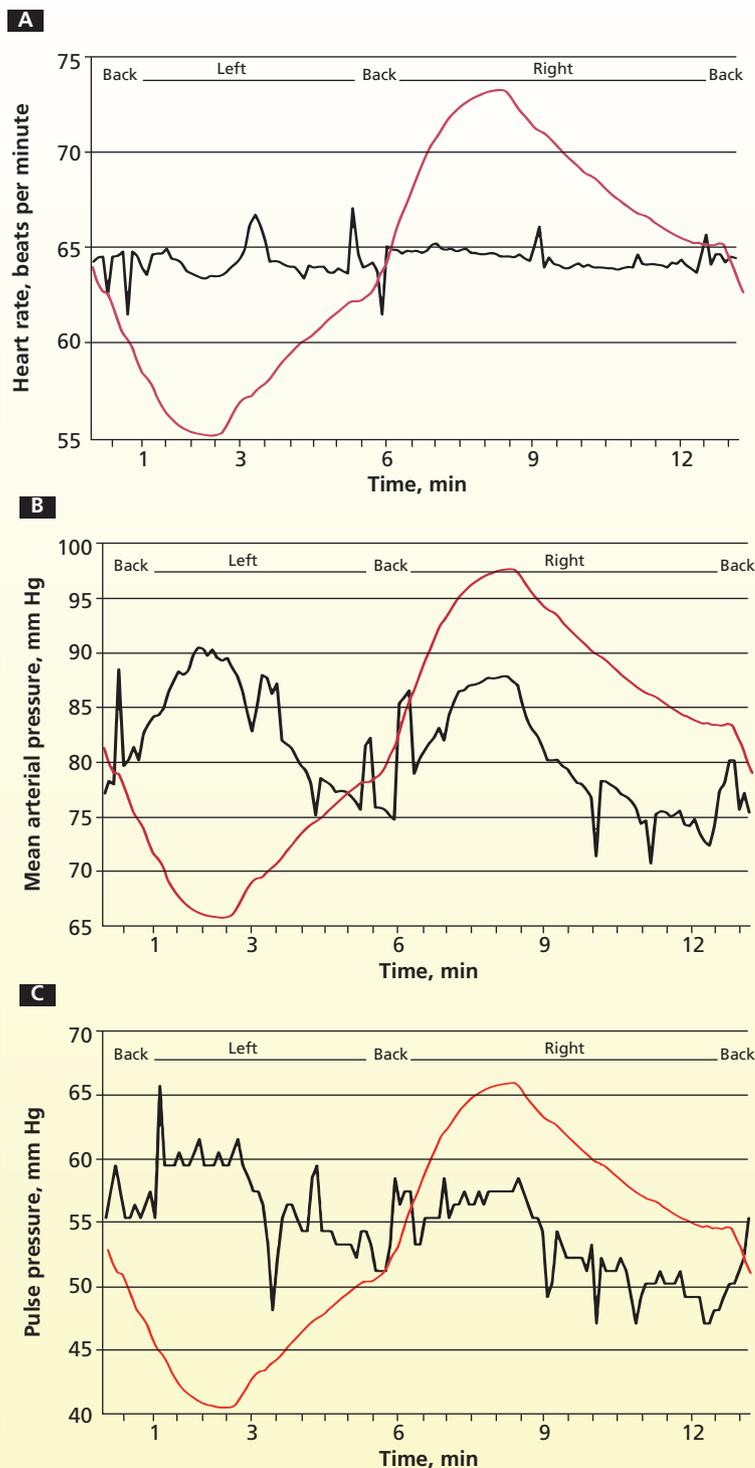
All patients in our study tolerated lateral turning. The patient whose data are shown in Figure 1 (P001) was the worst-case scenario in the study sample, with the greatest magnitude of response to turning. Clinicians are apprehensive about turning patients who have dramatic responses to turning. If turning were aborted on the basis of these grounds, patients with dramatic responses could conceivably be in the back position for days, putting them at risk for a host of pathological sequelae. One patient enrolled in our study could not start the study protocol because SBP in the back position decreased to less than that specified in a rotation “stopping rule.” Of note, patients with unstable hemodynamic status, defined for our study as SBP less than 90 mm Hg in the back position in patients receiving vasopressors, were not eligible to participate in the trial. Thus, our findings do not apply to patients receiving mechanical ventilation whose hemodynamic status is unstable.

Even though our patients were randomly selected by using a scientifically valid method for generalizability,<sup>20,21</sup> the small number of patients in the sample limits generalizability to adult patients treated with mechanical ventilation in a medical-surgical intensive care unit, particularly for the MAP and pulse pressure findings. Our findings provide an uncommon characterization of nearly continuous hemodynamic response to lateral rotation with manual and automated turning. Other investigators with comparable study objectives and populations of patients had far fewer data points than we did: 36 data points for heart rate<sup>2,22</sup> and MAP<sup>2</sup> with a sample size of 12. The nearly continuous characterization of hemodynamic changes increases the validity of our findings. Furthermore, the visual ensemble averages validate the statistical findings. Ensemble averaging offers advantages for characterizing such time-dependent data as heart rate, MAP, and pulse pressure; it improves precision and provides a graphical footprint to visually enhance interpretation.

**All patients in this trial tolerated lateral turning.**



**Figure 2** Manual-turn responses of heart rate (A, D), mean arterial pressure (B, E), and pulse pressure (C, F) in patient P001. A, B, and C show the time series for 4 individual turns from back to left position. D, E, and F show the corresponding ensemble averages for a complete turn cycle (back to left, left to back, back to right, and right to back). Vertical lines indicate the times of the turns.



**Figure 3** Ensemble averages from 20 complete turn cycles (back to left, left to back, back to right, right to back) for heart rate (A), mean arterial pressure (B), and pulse pressure (C), and a complete turn cycle (red line) for automated-turn patient P007.

### Conclusions and Implications

Lateral turning every 2 hours is a standard of care to minimize complications associated with immobility. Previous research has indicated adverse, albeit transient, hemodynamic effects with lateral

turning. Clinicians are therefore often reluctant to turn patients, fearing adverse effects in patients who are already physiologically compromised.

Our findings suggest that patients receiving mechanical ventilation in a medical-surgical intensive care unit may experience changes in heart rate, MAP, and pulse pressure when manually turned to 45° or more, but clinically important changes are transient and related to the turning maneuver. No differences between left and right lateral turning should be anticipated with turn angles of 50° or less. Clinically important hemodynamic changes subside within 15 minutes after the turn; modest changes may persist for up to 45 minutes. In our patients, the magnitude of change in heart rate, MAP, and pulse pressure was tolerated clinically, and patients remained in the lateral position for the 2-hour turn period. Automated lateral turning in a specialty bed designed to turn to an angle of 40° or more appears to have no adverse hemodynamic effects and may be a safer turning method for patients whose hemodynamic status is unstable. Further research with a larger sample size is indicated to validate our findings, and future research should be conducted in patients with hemodynamic compromise to determine their ability to tolerate manual and automated lateral rotation.

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**CNE Test** Test ID A152402: Hemodynamic Changes With Manual and Automated Lateral Turning in Patients Receiving Mechanical Ventilation

Learning objectives: 1. Identify hemodynamic changes that occur with manual repositioning. 2. Discuss hemodynamic changes that occur with continuous rotation. 3. Determine if use of manual or automatic turning is safe for medical-surgical patients receiving mechanical ventilation.

**1. The dependent variables in this study include which of the following?**

- a. Heart rate, mean arterial pressure (MAP), and pulse pressure
- b. Heart rate, blood pressure, and pulse rate
- c. Blood pressure, pulse oximetry, and heart rate
- d. Heart rate, cardiac rhythm, and MAP

**2. Which of the following clinical characteristics of the study participants was statistically significant?**

- a. Age
- b. Positive end-expiratory pressure (PEEP)
- c. Diagnosis
- d. None of the clinical characteristics proved to be statistically significant.

**3. Exclusion criteria for the study included which of the following?**

- a. Suspected or confirmed myocardial infarction
- b. Patient using mechanical ventilation requiring PEEP > 8 mm H<sub>2</sub>O
- c. Hemodynamic instability defined as systolic blood pressure < 90 mm Hg in the back position while on vasopressors
- d. Patient receiving gastric feeding via nasogastric tube

**4. Which of the following were limitations to the study identified by the researchers?**

- a. The need to collect more data points
- b. Small sample size
- c. Study did not include hemodynamically stable patients
- d. Poor adherence to the turning protocol

**5. A study of the back and lateral positions by Gawlinski and Dracup found which of the following?**

- a. Hemodynamic changes that occur with repositioning are constant.
- b. Turning from back to lateral positions increases venous return.
- c. There were no changes with hemodynamics related to position change from the back to lateral position.
- d. Hemodynamic changes that occur with repositioning are transient and return to baseline within 5 minutes.

**6. Which of the following are independent variables in this study?**

- a. Manual turning to prone position every 2 hours and continuous rotation with lateral rotation to 45°
- b. Manual lateral turn to 45° angle or greater every 2 hours for a 2-hour time interval and continuous rotation with lateral rotation to 40° or greater
- c. Heart rate, blood pressure, and pulse rate
- d. Heart rate, cardiac rhythm, and pulse rate

**7. Which of the following was the sample size for this study?**

- a. 7
- b. 10
- c. 13
- d. 45

**8. Blood pressure measurement could only be captured on patients with an arterial line in situ. This data was available on which of the following percentages of participants?**

- a. 54%
- b. 46%
- c. 22%
- d. 60%

**9. In the automated turn group, which of the following changes were seen in MAP?**

- a. Increase in MAP when turned to the left or right from the back position
- b. Increase in MAP when turned to the back position from the left or right position
- c. Decrease in MAP when turned to the left or right from the back position
- d. Decrease in MAP when turned to the back position from the left or right position

**10. The patient population studied included which of the following?**

- a. Hemodynamically stable burn patients requiring mechanical ventilation
- b. Hemodynamically stable trauma patients requiring mechanical ventilation
- c. Hemodynamically stable medical-surgical patients requiring mechanical ventilation
- d. Hemodynamically stable cardiovascular patients requiring mechanical ventilation

**11. If a subject had missing data points, the researchers did which of the following?**

- a. Removed the subject's data from the analysis
- b. Used linear interpolation to replace the data
- c. Used ensemble averaging to replace the data
- d. Duplicated the previous data point into the missing data slot

**12. Outlier and missing data represented which of the following percentages of the data collection?**

- a. < 1%
- b. 35%
- c. 46%
- d. 3.4%

Test ID: A152402 Contact hours: 1.0; pharma 0.0 Form expires: March 1, 2018. Test Answers: Mark only one box for your answer to each question.

- |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                                |                                |
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**Program evaluation**

- |  | Yes                      | No                       |
|--|--------------------------|--------------------------|
| Objective 1 was met  | <input type="checkbox"/> | <input type="checkbox"/> |
| Objective 2 was met  | <input type="checkbox"/> | <input type="checkbox"/> |
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| Content was relevant to my nursing practice  | <input type="checkbox"/> | <input type="checkbox"/> |
| My expectations were met   | <input type="checkbox"/> | <input type="checkbox"/> |
| This method of CE is effective for this content  | <input type="checkbox"/> | <input type="checkbox"/> |
| The level of difficulty of this test was:  |                          |                          |
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