ORIGINAL ARTICLE

Transcutaneous carbon dioxide monitoring could reduce physical contact with COVID-19 patients

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Background: Transcutaneous carbon di-oxide (TcCO2) monitoring can be valuable to allow non-invasive monitoring of plasma carbon dioxide (PaCO2) levels in patients with acute respiratory failure including those with novel coronavirus disease 2019 (COVID-19).

Methods: A pilot retrospective chart review was performed on critically-ill, adult patients admitted to the medical intensive care unit to assess correlation between TcCO2 and PaCO2 values. Obtained demographics, diagnoses, acute physiology, and chronic health evaluation II score (APACHE II), and Charlson co-morbidity index. TcCO2 values compared with corresponding blood gas PaCO2 values - including patients requiring inotropic agents. Microsoft Excel 2016 and IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, N.Y., USA) used for statistical analysis.

Results: Cohort consisted of 53 patients with acute respiratory failure from a variety of documented overlapping diagnoses. Thirty-one (58.4%) needed invasive mechanical ventilation, 20 (37.7%) required non-invasive ventilation with impending need for intubation and 2 patients (3.8%) who did not require oxygen delivery beyond high flow nasal cannula. Forty patients provided 121 instances of paired measurements of TcCO2 and PaCO2 where values were strongly correlated, $r(121)=.90$, $p<0.001$, including 54 instances where patients received one or more inotrope infusions at time of measurement. In the paired measurement cohort, the sum of instances per overlapping diagnosis accounted for 47[38.8%] COVID-19, 20[16.5%] interstitial lung disease, 69[57%] pneumonia, 74[61.2%] septic shock, 23[19%] acute exacerbation of chronic obstructive lung disease, 8[6.6%] pulmonary embolism, 13[10.7%] aspiration pneumonia, 7[5.8%] severe pulmonary hypertension, 10 [8.3%] cardiac arrest, 24[19.8%] congestive heart failure, 1[0.8%] each for neuromuscular respiratory failure and angioedema and 13[10.4%] stroke.

Conclusions: Continuous TcCO2 monitoring correlates well with PaCO2 offering opportunities to reduce the need for physical patient contact for frequent arterial punctures and arterial line placement among critically-ill patients with acute respiratory failure. It is a valuable addition to non-invasive monitoring of PaCO2 especially those with COVID-19 and irrespective of shock states.

Keywords: Transcutaneous, carbon di-oxide, acute respiratory failure, critically ill, COVID-19

INTRODUCTION

Concurrent with continued rising hospitalizations for acute respiratory failure from coronavirus 2019 disease (COVID-19) is an increasing demand on healthcare supplies, labor and space.[1] From January 21, 2020 to July 31, 2021, the total United States Covid-19 cases have reached a staggering 34,926,462 (10,520 per 100,000) including total deaths of 610,873.[2] Total hospitalizations since August 01, 2020 to July 30, 2021 was 2,402,156 and due to the large number of hospitalized patients, PPE shortage has been a significant issue as health care workers have been advised to optimized the use of PPE.[3,4] Non-invasive monitoring of plasma carbon di-oxide (CO2) levels may reduce the need for contact with patients who are in clinical isolation, such as those with COVID-19, thereby saving personal protective equipment for other purposes.[5] A recent systematic review defined a clinically acceptable range of difference between plasma arterial carbon dioxide (PaCO2) and transcutaneous CO2 (TcCO2) measurements to be within 7.5 mmHg. The same systematic review published significant discrepancies between TcCO2 and PaCO2 levels based on the context of utilization of the TcCO2 monitoring. However, within the subgroup analyses for adult patients within intensive care units the population limits of agreement were within clinically acceptable limits and even among different continuous TcCO2 monitoring devices.[6] In another recent study by Perkhofer et al TcCO2 monitoring was found to be a valuable tool that validated non-invasive monitoring of PaCO2 levels in patients with acute respiratory failure - including those with COVID-19.[7]

MATERIALS AND METHODS

In February 2020, our university hospital approved the use of SenTec Digital Monitoring Systems and SenTec V-Sign TTM Sensor 2 (SenTec Inc. Lincoln, RI, USA) on a trial basis for 6-12 months in critically-ill, adult patients admitted to the medical intensive care unit.[8] Per advise of our hospital’s value-analysis team members those patients who had TcCO2 monitoring were fully tracked by our respiratory therapists using a brief quality-control paper form in an effort to assess benefit to our hospital’s patient population. Each form recorded dates, diagnoses, corresponding PCO2 values, asked open-ended questions, provided an area for comments on whether TcCO2 monitoring was useful and offered an opportunity to report device related issues. Prior to implementing use, respiratory therapists received hands-on in-person training from SenTec on the appropriate use of these monitors and sensor placement. Sensors were placed in central sites including the anterior chest below the clavicle, upper arm, and upper back when prone. Using the data obtained we further evaluated the correlation of TcCO2 with PaCO2 in critically-ill adult patients aged ≥18 years with acute respiratory failure (including COVID-19). A pilot retrospective chart review was performed for those hospitalized between March – September 2020 to assess correlation between TcCO2 and PaCO2 values. The institutional review board (IRB) of University of Missouri, approved this retrospective study (IRB #2033723MU). We gathered demographics, diagnoses, acute physiology and chronic health evaluation II score (APACHE II), Charlson co-morbidity index and compared TcCO2 values with that of corresponding blood gas PaCO2 values - including patients requiring inotropic agents. Microsoft Excel 2016 and IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, N.Y., USA) were used for statistical analysis.

RESULTS

In total, continuous TcCO2 monitoring was used with 53 patients (male: female = 30:23, age 61.43 ± 14.15 years, body-mass index 35.9 ± 13.6 kg/m2) with acute respiratory failure from a variety of overlapping documented diagnoses: 11 COVID-19, 3 interstitial lung disease, 23 pneumonia, 15 septic shock, 17 acute exacerbation of chronic obstructive lung disease, 2 pulmonary embolism, 10 aspiration pneumonia, 4 each for severe pulmonary hypertension and cardiac arrest, 12 congestive heart failure, and 1 each for neuromuscular respiratory failure, angioedema and stroke. Charlson co-morbidity index was 4.43 ± 2.7 and APACHE II score was 20.19 ± 12.38 (see **Table 1**). Of all patients 31 (58.4%) needed invasive mechanical ventilation, 20 (37.7%) required non-invasive ventilation with impending need for intubation and 2 patients (3.8%) who did not require oxygen delivery beyond high flow nasal cannula.

Table 1. Summary of Patient Demographics Between Total Cohort and Patients with Paired TcCO2/PaCO2 measurements

Demographics	**Total in cohort (n=53)**	**Patients with paired measurements (n=40)**
Mean age	61.43	60.8
Male	30	24
Female	23	16
Mean height (cm)	169.72	169.56
Mean weight (kg)	104.6	100
Mean BMI	35.9	34.66
Mean APACHE II	20.19	20.43
Charlson comorbidity index (n)		
0	5	3
1	4	4
2	3	3
3	7	7
4	8	7
5	7	3
6	9	6
≥7	10	7
Mean Charlson CI score	4.43	4.1

Twelve patients, however, had TcCO2 readings which did not have a corresponding arterial blood gas or measurement times were not obtained and/or were missing and were thus excluded when comparing paired measurements. In total, forty patients provided 121 instances of paired measurements of TcCO2 and PaCO2 where values were strongly correlated, $r(121)=.90$, $p<0.001$, including 54 instances where patients were receiving inotrope infusion at the time of measurement (see Figure 1). In the paired measurement cohort, the sum of instances per diagnosis accounted for 47[38.8%] COVID-19, 20[16.5%] interstitial lung disease, 69[57%] pneumonia, 74[61.2%] septic shock, 23[19%] acute exacerbation of chronic obstructive lung disease, 8[6.6%] pulmonary embolism, 13[10.7%] aspiration pneumonia, 7[5.8%] severe pulmonary hypertension, 10 [8.3%] cardiac arrest, 24[19.8%] congestive heart failure, 1[0.8%] each for neuromuscular respiratory failure and angioedema and 13[10.4%] stroke (see **Table 2**).

Table 2. Summary of Overlapping Diagnoses and Percentage of Overlapped Diagnoses with Paired Measurements

Overlapping diagnoses	**Total in cohort (n=53)**	**Patients with paired measurements (n=40)**	**Overlapped diagnoses with paired measurements (%)***
COVID-19	11	11	38.84%
Interstitial lung disease	3	2	16.53%
Pneumonia	23	21	57.02%
Septic shock	15	14	61.16%
Exacerbation COPD/Asthma	17	13	19.01%
Pulmonary embolism	2	2	6.61%
Aspiration pneumonia	10	7	10.74%
Severe pulmonary hypertension	4	4	5.79%
Cardiac arrest	4	4	8.26%
Decompensated heart failure	12	10	19.83%
Neuromuscular respiratory failure	1	1	0.83%
Angioedema	1	1	0.83%
Stroke	1	1	10.74%

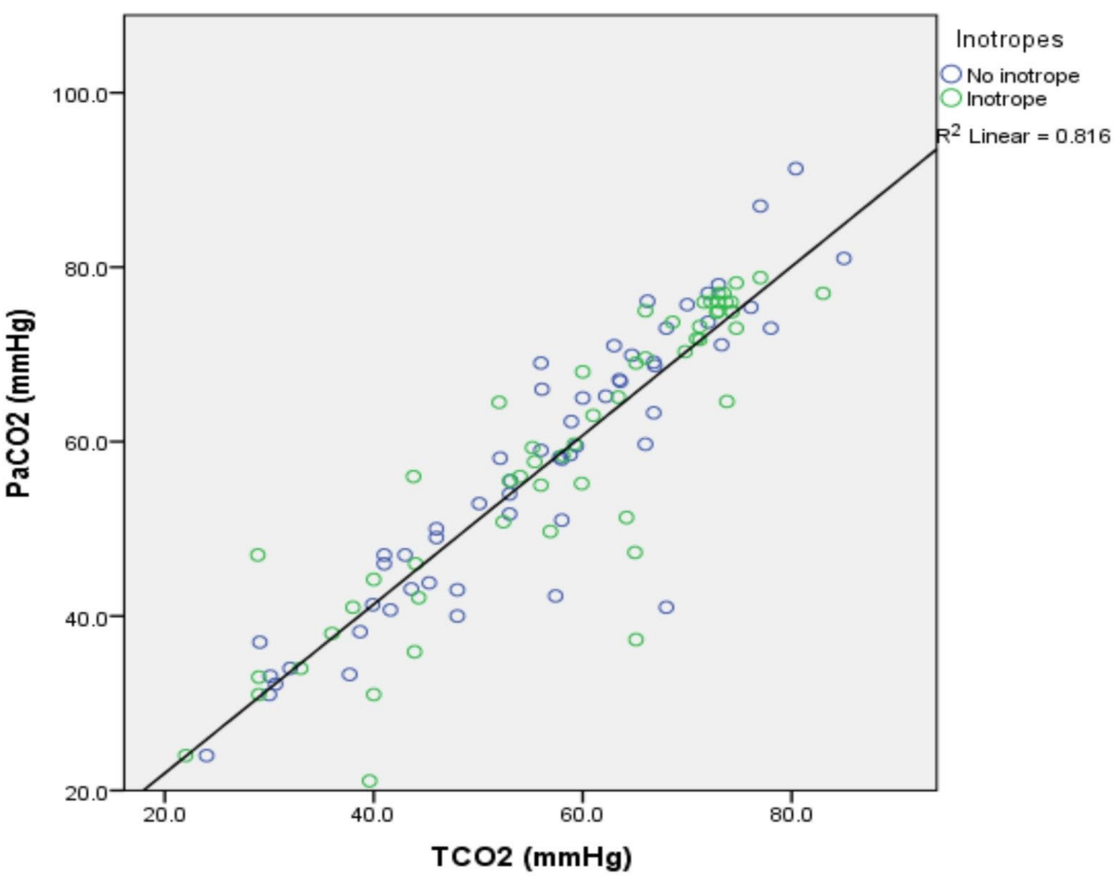
*Percentages based on the sum of paired measurements per diagnosis divided by total paired measurements. Several patients had more than 1 paired measurement.

Prior studies in adult patients have used an earlobe as the site for sensor placement, while we used core/central body areas as above. Our results are in line with observations from other authors that TcCO2 values correlate well with PaCO2 values among critically ill adult patients with acute respiratory failure, including COVID-19 - with or without refractory shock.[8-12] Through focused training of our respiratory therapists, we obviated any methodological errors that were observed by others.[13] Limitations include retrospective design, documentation discrepancies, lack of cost analysis for potential savings from reduced PPE usage, lack of data on the gradient between TcCO2 and PaCO2 (“gap CO2”) which can be useful for hemodynamic assessment and that many patients had COVID-19 related acute respiratory distress syndrome with concurrent high sedation requirements that may have led to medication-induced hypotension/shock.[14]

CONCLUSION

Continuous TcCO2 monitoring with the SenTec Digital Monitoring Systems correlates well with PaCO2, therefore, offering opportunities to reduce frequent arterial punctures, arterial line placement and related physical contact among critically ill patients with acute respiratory failure, especially those with COVID-19. Moreover, the correlation between TcCO2 and PaCO2 values was preserved irrespective of shock states. Given pandemic times and continued high hospitalization rates, any measure/technology that helps to reduce unnecessary contact with COVID-19 patients has the potential to save PPE and protect physicians and respiratory therapists from unnecessary exposure.

Figure 1: Correlation between simultaneous $TcCO_2$ and $PaCO_2$ measurements in those with and without shock*: PaCO2 – arterial carbon dioxide level,* TcCO2 *– Transcutaneous carbon dioxide level*



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