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SHORT REPORT

Electrocardiogram monitoring in the prone position in coronavirus disease 2019 acute respiratory distress syndrome

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Aims

Prone positioning is increasingly used for treating coronavirus disease 2019 (COVID-19)-induced acute respiratory distress syndrome (ARDS). In these high-risk patients for cardiovascular events who may spend more than 16 h a day in the prone position, an adequate monitoring of electrocardiogram (ECG) is mandatory. However, effects of prone positioning on the ECG are unknown as is the validity of the ECG recorded with electrodes placed dorsally. We aimed to compare ECG data obtained in the prone position from five electrodes positioned conventionally and dorsally, and to assess the effects of the change of position (from supine to prone) on the ECGs in patients with COVID-19 ARDS.

Methods and results

In patients with COVID-19 ARDS for whom the prone position was indicated, seven-lead ECG (frontal plane leads and V6) performed in the supine and the prone position with electrodes positioned conventionally and dorsally were compared. A total of 22 patients [20 (91%) males] were included. Among them, 10 (45%) patients had structural or ischaemic heart disease. After prone positioning, PR duration significantly increased and QRS duration significantly decreased whereas QT interval did not significantly change. In the prone position, there were excellent correlations between QRS axis, PR, RR, QRS, and QT intervals durations measured with electrodes placed on the torso and dorsally (with no change in the position of V6).

Conclusion

Prone positioning induced significant change in the ECG. In the prone position, ECG can be reliably monitored with four electrodes translated from conventional position to the back and with a precordial electrode left in V6 position.

Keywords ECG • QT interval • COVID-19 • Prone position • Acute respiratory distress syndrome

Implication for practice

- Monitoring electrocardiogram (ECG) in patients in the prone position is challenging.
- Turning patients from supine to prone shortens QRS duration.
- QT-interval remains unchanged after prone positioning.
- ECG obtained with electrodes placed dorsally are accurate.
- Guidelines on ECG monitoring in the prone position are needed.

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Introduction

A high proportion of patients admitted to the intensive care unit (ICU) for coronavirus disease 2019 (COVID-19) pneumonia require invasive mechanical ventilation for refractory hypoxaemia due to acute respiratory distress syndrome (ARDS).[1] Myocardial ischaemia/injury and drug-induced electrocardiogram (ECG) abnormalities (including repolarization disorders, arrhythmias, QT-interval prolongation) have been observed in up to three-quarters of these high-risk patients.[2–4] Consequently, reliable ECG monitoring is absolutely essential in this setting. This is particularly true for the QT interval, whose prolongation, frequently observed in COVID-19 patients, exposes them to life-threatening ventricular arrhythmias.[3,4] However, it can be difficult to properly monitor the ECG of patients treated with prone positioning, a procedure widely adopted to improve outcomes and indicated for at least 16 h per day in case of moderate-to-severe ARDS.[5,6]

Although the general recommendations for ECG monitoring in ICU[7] apply to ARDS, the electrodes cannot be positioned where they are usually placed (i.e. on the torso) in the prone position, because it would lead to both pressure skin lesions and artefacts. The prone position imposes the placement of the frontal plane electrodes dorsally and the removal of the precordial electrodes (except, perhaps, lead V6 that might be kept in its usual position). Of note, precordial derivations are recommended to measure QT interval.[7] Unfortunately, due to the paucity of data regarding the reliability of ECGs recorded in the prone position, there is no guideline on how to monitor/interpret ECG data in ARDS patients in this position.

The aim of the present study was to compare ECG data obtained in the prone position from five electrodes positioned conventionally and dorsally, and to assess the effects of the change of position (from supine to prone) on ECGs in patients with COVID-19 ARDS.

Methods

Following an international survey on ECG monitoring in the prone position, we conducted a prospective observational study in a 26-bed academic ICU in Lyon, France.

The investigation conforms with the principles outlined in the Declaration of Helsinki. The study was approved by the local institutional ethics committee (*Comité d'Ethique du CHU de Lyon*, no. 20-42). Informed consent was obtained from all patients or relatives.

For the survey, we sent a questionnaire by email to 28 ICUs of our network from nine countries (France, USA, India, Japan, Germany, The Netherlands, Spain, Italy, Switzerland) with high expertise in the use of the prone position for treating ARDS. One questionnaire was completed in each ICU and included six questions on ECG monitoring ['Do you have a written protocol describing the position of ECG electrodes in the supine position?'; 'Do you have a written protocol describing the position of ECG electrodes in the prone position?'; 'Number of derivations that are routinely monitored in your ICU?'; 'Which derivation(s) do you routinely monitor'; 'Do you routinely monitor ST segment and QT interval?'; 'Do you think that guidelines for monitoring ECG in patients in the prone position would be useful?'].

Consecutive, intubated, and mechanically ventilated patients with COVID 19-associated ARDS, whose ECG was continuously monitored using a five-electrode monitoring system (Intellivue MX800, Philips Healthcare, The Netherlands) and for whom prone positioning was indicated, were included. The limb electrodes were placed according to the Mason–Likar configuration (*Figure 1*), as recommended.[7]

Seven-lead ECGs (frontal plane leads and V6) were recorded with both a reference electrocardiograph (Cardiosoft, GE medical system, CT, USA) and with the bedside monitor (used for continuous ECG monitoring) just before and 5 min after positioning the patient in the prone position (*Figure 1*). This short interval was chosen to minimize the delayed changes induced by prone positioning on both the lungs and the heart (e.g. recruitment of collapsed lung, improvement of ventilation/perfusion mismatch, decrease in right ventricle afterload) which could alter the ECG. In the prone position, ECGs were also recorded with frontal plane electrodes translated to the back; whenever possible the V6 electrode was left in place (*Figure 1*). All ECGs were reviewed by both an intensivist physician and a cardiologist. Assessment of heart rate, QRS axis, RR, PR, and QRS intervals was based on an automated analysis of the ECG. Rhythm, QT intervals, ST segment deviation, Q wave, T wave, and U wave were assessed manually.

Data were expressed as median (first-to-third quartile) or number (percentage). Correlations and concordance between ECG data obtained with electrodes placed on the torso (reference method) and dorsally were assessed using the Rho Spearman's correlation test and the Bland–Altman analysis, respectively. Comparisons between data recorded in prone and supine position were performed using the Wilcoxon matched paired signed-rank test. Statistical analysis was performed with the GraphPad Prism 6 software (GraphPad Software, La Jolla, CA, USA). *P*-value <0.05 was considered as statistically significant.

Results

The survey, completed by 25/28 (89%) centres, indicated that only 7/25 (28%) ICUs had a protocol for ECG monitoring in the prone position; 17 (68%) centres claimed that guidelines should be developed for this routine monitoring. All but one centres used a five-electrode monitoring system; 13/25 (52%) routinely monitored two or more ECG derivations. QT and ST segment were routinely monitored in 8 (32%) and 12 (48%) centres, respectively.

A total of 22 patients [20 (91%) males] were included in the study; their median (first-to-third quartile, interquartile range) age was 65.5 (56–73) years and their body mass index was 31 (27–34) kg/m^2. Among them, 10 (45%) patients had structural or ischaemic heart disease, 10 (45%) had hypertension, and 6 (27%) had diabetes. Overall, 19 (86%) patients received norepinephrine and 3 (14%) required renal replacement therapy. An electrode could be positioned in the V6 position in all patients without any risk of pressure skin lesion, including after prone positioning.

For a given placement of electrodes and a given position, the ECGs simultaneously recorded with the reference electrocardiograph or with the bedside monitor were similar. At inclusion, only 3 (14%) patients had a normal ECG. We found atrial fibrillation in 3 (9%) ECGs, incomplete or complete bundle branch block in 7 (32%) ECGs, repolarization disorders in 13 (59%) ECGs, pathological Q waves in 4 (18%) ECGs and prolonged QT intervals in 6 (27%) ECGs. Respiratory mechanics did not differ in the supine and prone positions whereas, after prone positioning, PR duration significantly increased and QRS duration significantly decreased (*Table 1*). Other ECG parameters did not significantly change in the prone position compared to supine position (*Table 1*).

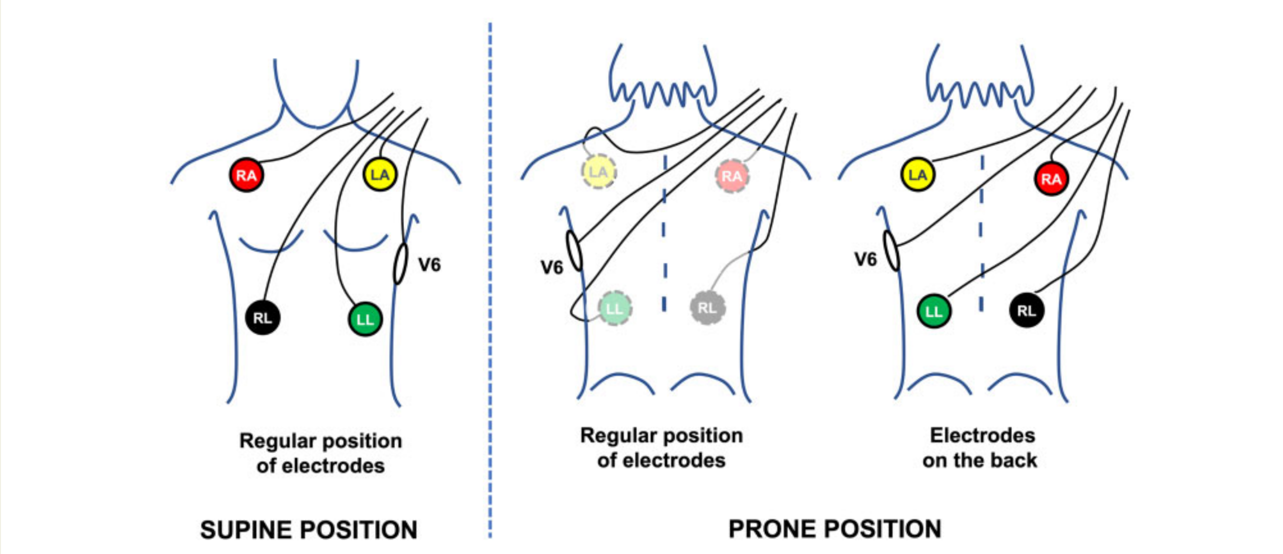

Figure 1 Position of electrocardiogram electrodes in the supine and prone position. Seven-lead electrocardiogram was obtained with five electrodes (right arm, left arm, right limb, left limb, V6 lead) placed in regular position (Mason–Likar configuration) in the supine position (image on the left) and in the prone position (image on the middle); electrocardiogram was also obtained with electrodes placed dorsally in the prone position (image on the right). LA, left arm; LL, left limb; RA, right arm; RL, right limb; V6, V6 lead.

Table 1 Changes in respiratory and electrocardiogram parameters from the supine to the prone position

Parameter	Supine position ($n = 22$)	Prone position ($n = 22$)	*P*-values
Respiratory data			
Tidal volume (mL/kg PBW)	5.9 (5.8–6.0)	5.9 (5.8–6.0)	0.829
PEEP (cmH_2O)	11 (10–13)	11 (10–13)	0.417
FiO_2 (%)	50 (45–85)	50 (45–80)	0.500
Plateau pressure (cmH_2O)	22 (21–24)	23 (20–24)	0.849
Crs (mL/cmH_2O)	41 (33–48)	44 (32–49)	0.929
Inspired fraction of oxygen	50 (45–80)	50 (45–85)	0.500
ECG data[a]			
Heart rate (b.p.m.)	69 (59–88)	74 (66–88)	0.613
QRS axis (degree)	26 (−1 to 57)	29 (0–47)	0.955
RR interval (ms)	870 (680–1020)	820 (678–915)	0.058
PR interval (ms)	148 (129–159)	156 (136–160)	0.049
QRS duration (ms)	94 (87–98)	68 (71–80)	<0.001
QT interval (ms)	400 (360–435)	380 (360–400)	0.117
Corrected QT (Bazett) (ms)	436 (428–454)	431 (418–450)	0.622

Data are expressed as median (first-to-third quartile).
[a]Electrodes were placed in the regular position on the torso (Mason–Likar configuration).
Crs, compliance of the respiratory system; ECG, electrocardiogram; FiO_2, inspired fraction of oxygen; PBW, predicted body weight; PEEP, positive end-expiratory pressure.

In the prone position, there were excellent correlations between QRS axis, PR, RR, QRS, and QT intervals durations measured with electrodes placed on the torso and dorsally (*Figure 2*). Biases and limits of agreements are presented on Bland–Altman plots in *Figure 2*. There were no significant differences in other ECG parameters, including ST-T segment.

Discussion

The main findings of this study were that (i) the prone position induced significant changes in ECG, notably a decrease in QRS duration and (ii) that frontal plane leads can monitor the ECG as reliably with the electrodes adequately positioned dorsally as with the

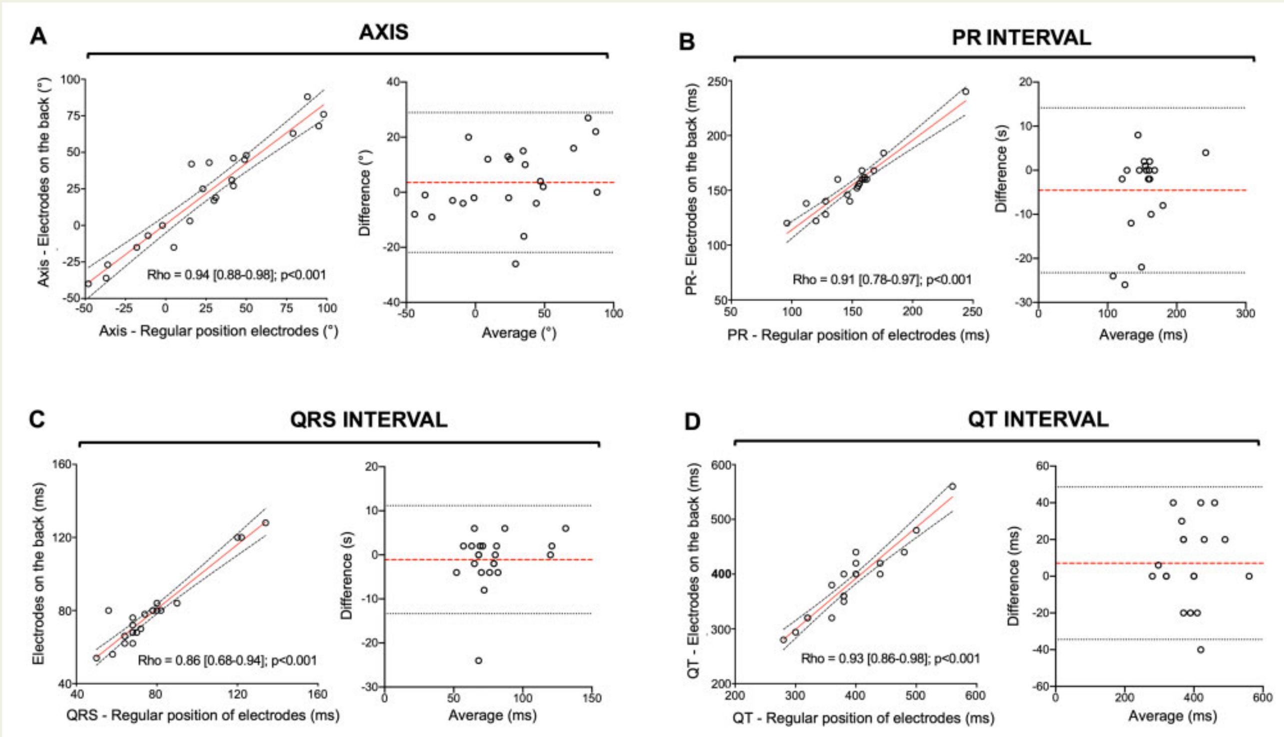

Figure 2 Spearman's correlation and Bland–Altman plots for QRS axis, PR, QRS, and QT intervals measured in the prone position with regular and dorsal placement of electrodes. The data of QRS axis (*A*), PR interval (*B*), QRS interval (*C*), and QT interval (*D*) are presented with Spearman's correlation part and Bland–Altman plots (left and right side of each panel, respectively) between all measurements. For correlation plots, the red line shows the linear regression and dashed lines its 95% confidence interval. For Bland–Altman plots, red dashed lines show the bias and black dashed lines the 95% limits of agreement.

electrodes positioned on the torso in patients in the prone position (with V6 left in place) for COVID-19-induced ARDS. We also highlighted that prone positioning did not induce change in QT interval.

Previous studies in both healthy participants and COVID-19 patients showed that V1–V5 leads could not be reliably recorded with standard precordial electrodes translated to the back.[8,9] As precordial leads remain useful to detect myocardial ischaemia,[7] V6 monitoring, which was feasible in all patients, is an option. More importantly, this derivation is recommended to properly assess the QT interval.[7]

COVID-19 patients are at risk of prolonged QT intervals, even in the absence of antiviral drugs known to increase QT interval.[3,4] In our survey, only one-third of the ICUs routinely monitored QT interval. Inadequate ECG monitoring in the prone position may lead to undetected QT-interval prolongation, which increases risk of ventricular arrhythmias. As cardiac arrest in the prone position is particularly difficult to manage, QT monitoring in these patients should be standardized and should include the systematic use of V6.

Shortening of QRS duration in the prone position is an interesting observation that has been previously reported in healthy participants.[8] An explanation could be that prone positioning induces a decrease in ventricular volume (due to the compression of the heart) that might decrease intraventricular conduction times. The reduction in ventricular volume during the prone position in patients with COVID-19 ARDS has been recently suggested using trans-oesophageal echocardiography.[10] The increase of PR duration in the prone position could be due to right atrial enlargement. These changes were not explained by a change in heart axis. Indeed, contrary to data in healthy subjects,[8] QRS axis was similar in the supine and prone positions, suggesting that the heart did not switch forward, probably because high positive end-expiratory pressure prevented this phenomenon.

The study has several limitations. Since the clinical part of the study was conducted in a single centre, included a limited number of patients and a low proportion of female, the generalizability of these results might be limited. Therefore, larger and multicentric studies would be necessary to confirm our results. Another limitation is that we did not assess whether adequate ECG monitoring that includes V6 in the prone position would improve the detection of arrhythmias, ischaemia, and/or QT-interval prolongation. Future investigations are needed to answer this important question. It would be also interesting to evaluate whether change in QRS duration with position would be used as a non-invasive parameter of the effects of the prone position on heart volume.

In conclusion, the present study shows that the prone position may alter the ECG, particularly the shortening of the QRS duration, and that the ECG recorded with frontal electrodes translated from Mason–Likar position to the back with V6 left in place, is reliable. These data could be of great help for the development of urgently needed guidelines for monitoring ECG in ARDS patients (with or without COVID-19) treated with prone positioning.

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Conflict of interest: The authors declare that they have no competing interests.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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