Technique of on-line analysis of diaphragmatic electromyogram activity in the newborn

B. Chambille, G. Vardon, J.P. Monrigal, M. Dehan*, C. Gaultier**

On-line analysis of diaphragmatic EMG (EMGdi) should be useful in the weaning period, especially in newborns who have been shown to be at risk of respiratory muscle fatigue [1]. A previous study by Müller et al. [1] in newborns concerned only off-line analysis of the high over low frequencies ratio (H/L). In the present study we tested an on-line system of analysis in healthy preterm newborns. Furthermore, we compared the H/L ratio, the centroid frequency [2-4] and the modal frequency [5].

Methods and subjects

We studied seven healthy preterm newborns, free of respiratory disease, whose gestational age was 31 wks (range from 28-34 wks) and whose postnatal age was 16 days (range 2-27 days). Body weight at the time of the study was 1.660 g (range 1.350-2.190 g).

All subjects were tested whilst spontaneously breathing during sleep, in the supine position, inside an incubator. The EMGdi was recorded using two surface electrodes (Beckman) placed in the right 7th and 8th interspaces, between the mid-clavicular and mid-axillary lines. The inter-electrode distance was 20 mm and the inter-electrode impedance was lower than 10 kΩ. The signals were filtered to allow passage of frequencies between 10-1000 Hz [4-7] and amplified (preamplifier and amplifier Gould 13-4615-58). The signals were displayed on a Tektronix 5111A storage oscilloscope and processed using a microcomputer (Apple IIe), using two disc drives, a printer, a real time clock card (Nautic HC-1) and 12 bits A/D convertor (SDM 837). Programs were written in machine code and Basic Microsoft (Beagle compiler-Beagle Bross Micro Software Inc.).

Data analysis

First step. The EMGdi signal was sampled during 4.65 s and monitored (fig. 1. panel a). The investigator placed horizontal lines on the screen of the computer. The vertical position of the lines determined the threshold for further QRS detection. The length of the lines corresponded to the time window during which the EMGdi signal would be digitized during the second step of the analysis. The QRS artifacts were automatically removed from the stored EMGdi signal (fig. 1. panel b): when the signal was greater than the QRS complex detection threshold, the 12 preceding and the 12 following data points of the EMGdi were set at zero. The residual artifact-free EMGdi signal was rectified. The mean amplitude (A) of the EMGdi was calculated (fig. 1. panel c). A would be the reference of mean amplitude value for detection of EMGdi inspiratory bursts during the second step of analysis.

Second step. After one QRS complex and during the time window, the EMGdi signal was digitized (256 data points and sampling frequency of 1024 Hz) (fig 2. upper panel), rectified and its mean amplitude (a) calculated. When a of the sample was less than the mean reference amplitude A, the signal was rejected, being presumably an expiratory signal. When a of the sample was greater than A x 3, the signal was also rejected being presumably modified by movement artifacts. Then the accepted
samples were analysed using: 1) auto-regressive model
with calculation of the modal frequency (Fo) [5]; 2) power
spectral analysis with determination of the centroid fre-
quency (Fc) (fig. 2, lower panel) and of the H/L frequen-
cies ratio (150–120/60–30 Hz).

For each subject all Fo and Fe data were compared
using the paired t-test. The coefficient of variation and
the percentage of rejected calculations between the H/L
ratio, Fe and Fo were compared using the Wilcoxon test.

Results

Table 1 shows the mean individual values (±1 sd), the
coefficient of variation and the percentage of rejected
calculations for the H/L ratio, Fo and Fe. Mean individual
Fc ranged from 46-62 Hz and mean individual Fo
from 49–70 Hz. When all Fo and Fe calculations were
compared for each subject, Fe was lower than Fo in six
of the seven subjects, but the level of significance was
reached in only four subjects (nos 2, 4, 6 and 7, table 1)
(p<0.001). The coefficient of variation for Fo and Fe was
not significantly different, whereas the coefficient of
variation for the H/L ratio was significantly higher than
for Fe, p<0.001. The percentage of EMGdi samples for
which calculations were rejected was significantly higher
for Fo than Fe, p<0.001. Figure 3 shows the relationship
between all accepted calculations for Fo and Fe:
Fe (Hz)=11.8+0.71 Fo (Hz), r=0.81, p<0.001.

Conclusion

As in previous studies on EMGdi in the newborn we
used surface electrodes [1, 6, 7]. Although there is a
possibility of artifacts from surface electrodes, it has been
shown that EMGdi recorded in infants from intercostal
sites exhibit spectra which are very similar to those from
subcostal diaphragm surface recordings [1] which in turn
resemble EMGdi obtained from an oesophageal electrode
[8]. However, contamination of diaphragmatic surface
signals with EMG from other muscles cannot be excluded.

Different off-line techniques to remove QRS artifacts
on the EMGdi have previously been proposed [4, 10]. In
the present study we used an automatic gating technique.
Another problem which arises is sampling inspiratory
bursts for computer analysis of the EMGdi. A respira-
tory signal can be used to sample the EMG signal [1] during
the inspiratory part of the respiratory cycle [5]. In
the present study we did not use a respiratory signal. The
aim of our investigation was to provide an on-line analy-
sis which could be used in mechanically ventilated
newborns in whom a minimal apparatus is required. Our
method of inspiratory burst determination was based on
the mean reference amplitude A defined on the QRS free
EMGdi.

As previously observed in adults [1], the coefficient of
variation for the H/L ratio was significantly higher than
for Fe in preterm newborns. Fe values (table 1) were
close to the mean Fe observed in one full-term newborn
by NUGENT and FINLEY [7]. As in adults, Fo and Fe were
significantly related [5], however, Fe was significantly
less than Fo in four of the seven preterm newborns. The
Table 1. - High-to-low frequency ratio, modal frequency and centroid frequency in seven healthy preterm newborns

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number of EMGdi samplings</th>
<th>H/L</th>
<th>Fo</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>0.08</td>
<td>49</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>0.16</td>
<td>58</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>0.13</td>
<td>53</td>
<td>49</td>
</tr>
<tr>
<td>4</td>
<td>180</td>
<td>0.12</td>
<td>60</td>
<td>53</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>0.12</td>
<td>60</td>
<td>53</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>0.12</td>
<td>60</td>
<td>53</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>0.21</td>
<td>69</td>
<td>62</td>
</tr>
</tbody>
</table>

EMGdi: diaphragmatic electromyogram; H/L: high low ratio of the power spectrum (150-120/60-30 Hz); Fo: modal frequency; Fe: centroid frequency; st/mean: coefficient of variation; failure %: percentage of EMG diaphragmatic samples for which Fo and Fe calculations were rejected, i.e. Fo or Fe <30 Hz or >150 Hz.

percentage of rejected calculations for Fo was significantly higher than for Fe. Thus, in our seven preterm newborns, Fe appears to be the best index of EMGdi analysis with a low percentage of rejection and a reasonable coefficient of variation. Further investigations are needed to justify the choice of Fo as the best index of EMGdi analysis in sick newborns.

In summary, an on-line analysis of EMGdi recorded using surface electrodes was tested in healthy preterm newborns. During the weaning period, our system should be useful for monitoring EMGdi in mechanically ventilated newborns. In addition to gas exchange monitoring, a decline of Fe in the EMGdi power spectrum may allow early detection of the development of diaphragmatic fatigue.

Acknowledgements: The authors are grateful to S. Rouchaville for typing the manuscript.

References


RÉSUMÉ: L'étude fournit une analyse on-line de l'activité diaphragmatique électromyographique chez les nouveau-nés (EMGdi). EMGdi a été enregistré au moyen d'électrodes de surface. Les signaux d'EMGdi ont été traités par un micro-ordinateur (Apple Ile). La fréquence contrôlée (Fc) et le rapport des fréquences élevées sur les fréquences basses du spectre de puissance, ont été calculés. Par ailleurs, la fréquence modale (Fo) a été comptée par un modèle auto-régissant du signal électromyographique. L'analyse EMGdi a été réalisée chez 7 nouveau-nés avant terme respirant spontanément. Fe s'étend de 46 à 62 Hz. Fe est significativement plus bas que Fo chez 4 des...
7 nouveau-nés prématurés. Le coefficient de variation pour Fe est significativement plus bas que pour la relation H/L (p<0.001). Les coefficients de variation pour Fo et Fe ne sont pas significativement différents, mais le pourcentage de calculs rejetés pour Fo est significativement plus élevé que pour Fe (p<0.01). Pour cette raison, chez les nouveau-nés prématurés en bonne santé, Fe semble le meilleur index d’analyse d’EMGdi.

*Eur Respir J.*, 1989, 2, 883–886