COMPUTERISED PROGRAM TO COMPARE TOLERANCE OF DIALYSIS PATIENTS TO DIFFERENT DIALYSIS SCHEDULES

F Lonati, B Pea, A Castellani

Umberto I Hospital, Brescia, Italy

Summary

In the attempt to compare rapidly and easily the tolerance of dialysis patients to different dialysis schedules, we developed a computerised program for use with a personal computer.

As a first application of this program we analysed the effects of long-term substitution of bicarbonate for acetate in reducing dialysis hypotension.

Introduction

When the results of different therapeutic strategies vary slightly and are subject to variation with time or to multifactorial interference, it is necessary to perform long-term studies and to examine all aspects of the question. It is necessary to collect exact multiple data and to elaborate them frequently, rapidly, and without mistake. In such cases the use of the computer is no doubt necessary.

Personal computers have an adequate storage and computational power; however, the software for medical application is frequently inadequate for the task and/or expensive or too difficult to use. It is also important to reduce or to avoid the need to interact with the computer through an intermediary [1].

For these reasons we have developed a program applicable to a personal computer to study the value of different dialysis schedules in reducing dialysis intolerance. Initially we have applied it to the analysis of a still controversial question: the value of substituting bicarbonate for acetate to reduce dialysis-induced hypotension [2–6].

Material and methods

We used an Olivetti Personal Computer M20 ST 256 K Bytes RAM memory. The program is prepared both in English and Italian.

This program may be used also by people not expert in basic language, to
compare the tolerance to two or more kinds of treatment in the same population or in different populations.

Once the prospective study is planned for each type of treatment or group of patients, the following data are collected and recorded for each dialysis:

- **patient name or marker**
- **date**
- **marker of type or phase of treatment**
- **pre-dialysis and lowest observed systolic and diastolic blood pressure (BP)**
- **pre-dialysis and post-dialysis body weight (BWT)**
- **number of symptomatic hypotension episodes (SHY)**
- **time of appearance of first SHY**
- **other clinical incidents (cramps, headache, vomiting, extrasystoles, tachycardia)**
- **saline and hypertonic sodium chloride bolus injected**
- **run duration.**

The data are subjected to automatic quality control and then compacted and recorded.

These data, and the ones mathematically deducted by the computer (mean BP; mean Δ BP; Δ systolic BP; Δ diastolic BP; Δ BWT; Δ BWT % dry BWT per run; Δ BWT % dry BWT/hour) can be quickly picked out for a single patient or for a chosen group, for a selected period or for the total period of each schedule.

In a few seconds the computer elaborates, according to the request, the following stages, not necessarily in sequence:

A) **Graphically the trend in symptomatic hypotension together with hourly ultrafiltration % BWT; or delay of appearance of first symptomatic hypotension; or systolic and diastolic mean blood pressure absolute or as Δ % of pre-dialysis value; or other incidents; or saline and hypertonic NaCl bolus injected.**

B) **The numerical elaboration (mean, SD, % frequency) of each parameter and/or statistical comparison (‘t’ test, ‘t’ test for paired data, Chi square test, F test) of the studied parameters for the different periods, populations or schedules.**

C) **The linear correlation among the different parameters with visualisation of the scattering of the points, the number of the examined pairs, the regression equation and r.**

D) **The changes of frequency or of intensity of a phenomenon by the use of CUSUM analysis: the swings from the overall mean in the chosen period and their importance and length are visualised [7,8].**

Examples of the above applications are given in Figure 1, from A to D.

### The patients

As a first application of our computerised program, we studied 16 patients aged 54 ± 16 (male 6; female 10), with frequent symptomatic hypotension episodes in a standard dialysis schedule (QB 220–300ml/min; QD 500ml/min; flat plate
Figure 1A. Example of elaboration stage: for further explanation see section on 'Material and methods'
<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequent</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
<th>Chi Squared</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHV / DIALYSIS</td>
<td>41.24</td>
<td>.57</td>
<td>.77</td>
<td>97</td>
<td>.42</td>
<td>.70</td>
<td>95</td>
<td>1.36</td>
<td></td>
</tr>
<tr>
<td>DIAL. WITH SHV</td>
<td>17.53</td>
<td>.25</td>
<td>.57</td>
<td>97</td>
<td>.42</td>
<td>.85</td>
<td>95</td>
<td>-1.65</td>
<td></td>
</tr>
<tr>
<td>DIAL. WITH BOLUS INF.</td>
<td>7.22</td>
<td>.14</td>
<td>.52</td>
<td>97</td>
<td>.16</td>
<td>.57</td>
<td>95</td>
<td>-1.17</td>
<td></td>
</tr>
<tr>
<td>APPEARANCE 1st SHY MIN</td>
<td>150.25</td>
<td>48.35</td>
<td>34.34</td>
<td>60</td>
<td>50.22</td>
<td>30.22</td>
<td>30</td>
<td>-2.13</td>
<td></td>
</tr>
<tr>
<td>BODY WEIGHT (pre) Hg</td>
<td>515.34</td>
<td>11.89</td>
<td>30.05</td>
<td>97</td>
<td>10.32</td>
<td>5.82</td>
<td>95</td>
<td>-3.82</td>
<td></td>
</tr>
<tr>
<td>BODY WEIGHT (post) Hg</td>
<td>468.20</td>
<td>7.70</td>
<td>69.05</td>
<td>97</td>
<td>6.67</td>
<td>3.15</td>
<td>95</td>
<td>-7.15</td>
<td></td>
</tr>
<tr>
<td>RUN DURATION</td>
<td>144.43</td>
<td>33.50</td>
<td>19.46</td>
<td>97</td>
<td>21.27</td>
<td>10.56</td>
<td>95</td>
<td>-5.23</td>
<td></td>
</tr>
<tr>
<td>SYSTOLIC BF (pre) mm Hg</td>
<td>170.00</td>
<td>17.28</td>
<td>10.56</td>
<td>97</td>
<td>10.51</td>
<td>5.32</td>
<td>95</td>
<td>-1.03</td>
<td></td>
</tr>
<tr>
<td>SYSTOLIC BF (post) mm Hg</td>
<td>110.62</td>
<td>28.50</td>
<td>14.32</td>
<td>97</td>
<td>30.11</td>
<td>15.36</td>
<td>95</td>
<td>-1.35</td>
<td></td>
</tr>
<tr>
<td>DIASTOLIC BF (pre) mm Hg</td>
<td>87.63</td>
<td>9.61</td>
<td>4.56</td>
<td>97</td>
<td>8.63</td>
<td>4.56</td>
<td>95</td>
<td>1.94</td>
<td></td>
</tr>
<tr>
<td>DIASTOLIC BF (post) mm Hg</td>
<td>72.22</td>
<td>11.26</td>
<td>5.56</td>
<td>97</td>
<td>11.04</td>
<td>5.56</td>
<td>95</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>DELTA BMT Hg</td>
<td>27.14</td>
<td>7.43</td>
<td>4.56</td>
<td>97</td>
<td>8.30</td>
<td>4.56</td>
<td>95</td>
<td>-1.69</td>
<td></td>
</tr>
<tr>
<td>DELTA BMT I</td>
<td>5.36</td>
<td>1.50</td>
<td>0.92</td>
<td>97</td>
<td>1.70</td>
<td>0.92</td>
<td>95</td>
<td>-1.34</td>
<td></td>
</tr>
<tr>
<td>DELTA BMT I / HOUR I</td>
<td>1.72</td>
<td>0.39</td>
<td>0.28</td>
<td>97</td>
<td>0.43</td>
<td>0.28</td>
<td>95</td>
<td>1.56</td>
<td></td>
</tr>
<tr>
<td>MEAN BF (pre) mm Hg</td>
<td>115.09</td>
<td>11.04</td>
<td>6.04</td>
<td>97</td>
<td>10.42</td>
<td>5.36</td>
<td>95</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>MEAN BF (post) mm Hg</td>
<td>91.62</td>
<td>18.45</td>
<td>9.43</td>
<td>97</td>
<td>18.46</td>
<td>9.43</td>
<td>95</td>
<td>-1.03</td>
<td></td>
</tr>
<tr>
<td>DELTA MEAN BF mm Hg</td>
<td>33.47</td>
<td>20.38</td>
<td>14.32</td>
<td>97</td>
<td>18.05</td>
<td>9.43</td>
<td>95</td>
<td>1.26</td>
<td></td>
</tr>
<tr>
<td>DELTA SYST. BF mm Hg</td>
<td>20.57</td>
<td>17.04</td>
<td>9.43</td>
<td>97</td>
<td>16.35</td>
<td>9.43</td>
<td>95</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td>DELTA SYST. BF I</td>
<td>59.38</td>
<td>33.37</td>
<td>17.58</td>
<td>97</td>
<td>31.62</td>
<td>17.58</td>
<td>95</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>DELTA SYST. BF I              29.49</td>
<td>18.37</td>
<td>11.32</td>
<td>97</td>
<td>17.66</td>
<td>11.32</td>
<td>95</td>
<td>1.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DELTA DIAST. BF mm Hg</td>
<td>20.52</td>
<td>15.57</td>
<td>8.92</td>
<td>97</td>
<td>14.67</td>
<td>8.92</td>
<td>95</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td>DELTA DIAST. BF I</td>
<td>27.87</td>
<td>17.11</td>
<td>10.56</td>
<td>97</td>
<td>17.32</td>
<td>10.56</td>
<td>95</td>
<td>1.54</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1B. Example of elaboration stage: for further explanation see section on 'Material and methods'
Figure 1D. Example of elaboration stage: for further explanation see section on 'Material and methods'
or hollow fibre dialysers with 0.9–1 m² effective surface area, 140 mmol/L dialysate sodium).

They were analysed in acetate dialysis (38–40 mmol/L) for at least six months and then they were switched to bicarbonate dialysis for a mean of 13 months.

QB, QD, run duration, dialysers, drugs, dialysate sodium concentration were the same as for acetate dialysis.

Results

The patients were switched to bicarbonate dialysis only after observing the long-term stabilisation of the following data on acetate dialysis: percentage hypotensive dialyses; number of hypotensive episodes for each dialysis; number of NaCl bolus injected; time of appearance of first symptomatic hypotension; Δ systolic, Δ diastolic, Δ mean blood pressure.

In Figure 2 CUSUM analysis of the number of hypotensive episodes for each dialysis (A) and of Δ systolic blood pressure (C) are presented. The stabilisation in the last 50 acetate dialyses is evident.

When switched to bicarbonate dialysis, CUSUM analysis reveals a biphasic trend for all the above parameters: improvement in the first 15–20 dialyses, followed by a deterioration (Figure 2B and Figure 2D).

If we compare the total acetate dialyses (1,576) with the total bicarbonate dialyses (3,087) no significant differences are detectable for all the analysed parameters.

However, if we examine selected periods or single patients some differences appear.

Table I reports the statistical comparison for the whole population of the last 50 acetate dialyses with the first 20 bicarbonate dialyses, with the bicarbonate dialyses 21–50 and with the last 20 bicarbonate dialyses.

During the four examined periods the pre-dialysis blood pressure, the hourly ultrafiltration % body weight, the pre-dialysis body weight and the dry body weight do not significantly change.

It is noteworthy that the hypotension indices improve in the first 20 bicarbonate dialyses and then worsen. There is no difference among the stabilisation periods in the whole population.

When we studied patient by patient, however, we observed that in two out of 16 patients the improvement remained constant.

Discussion and conclusions

The use of a personal computer with appropriate software prepared by ourselves appears very useful to compare with accuracy the tolerance of a single patient or of a group of patients to different schedules of dialysis.

It is easy to evaluate the trends, and to have in any moment and in a few minutes for instance up-to-date results with statistical analysis.

It is possible to make objective evaluation of the 'stabilisation' and to demonstrate the value of the treatment variation in a patient or in a group of patients,
Figure 2. CUSUM analysis of the number of hypotensive episodes for each dialysis (A and B) and of Δ systolic blood pressure (C and D). The last 50 acetate dialyses are shown in A and C, the first 50 bicarbonate dialyses in B and D.
CUSUM ANALYSIS  NUMBER OF HYPOTENSION FOR EACH DIALYSIS  BICARBONATE DIALYSIS
( 16 PATIENTS )
stand. units = 4 SD, overall mean .35, SD .147902

574 mg
WEIGHT post

551 mg

overall m.

124 mmHg

106 mmHg

Figure 2. CUSUM analysis of the number of hypotensive episodes for each dialysis (A and B) and of \( \Delta \) systolic blood pressure (C and D). The last 50 acetate dialyses are shown in A and C; the first 50 bicarbonate dialyses in B and D.
CUSUM ANALYSIS DELTA SYSTOLIC BLOOD PRESSURE (mm) ACETATE DIALYSIS
(16 PATIENTS) last 50 runs

stand. units = 4.50, overall mean = 35.58, SD = 7.432

573 mmHg
WEIGHT post

555 mmHg

overall m.

125 mmHg
PAM pre

101 mmHg

10 20 30 40 50

Figure 2. CUSUM analysis of the number of hypotensive episodes for each dialysis (A and B) and of Δ systolic blood pressure (C and D). The last 50 acetate dialyses are shown in A and C, the first 50 bicarbonate dialyses in B and D.
Figure 2. CUSUM analysis of the number of hypotensive episodes for each dialysis (A and B) and of Δ systolic blood pressure (C and D). The last 50 acetate dialyses are shown in A and C, the first 50 bicarbonate dialyses in B and D.
TABLE I. Comparison of the last 50 acetate dialyses with the first 20 bicarbonate dialyses, with the bicarbonate dialyses 21–50 and with the last 20 bicarbonate dialyses for the whole population

<table>
<thead>
<tr>
<th></th>
<th>ACETATE last 50 dialyses</th>
<th>ACETATE first 20 dialyses</th>
<th>BICARBONATE 21–50 dialyses</th>
<th>BICARBONATE last 20 dialyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIALYSIS NR</strong></td>
<td>800</td>
<td>320</td>
<td>480</td>
<td>320</td>
</tr>
<tr>
<td>Hypotensive DL % frequency</td>
<td>29.75 ***</td>
<td>18.44 *</td>
<td>24.79 *</td>
<td>33.09 *</td>
</tr>
<tr>
<td>Time of appearance 1st SHY min</td>
<td>161±30 *</td>
<td>177±31 **</td>
<td>155±38 *</td>
<td>162±37</td>
</tr>
<tr>
<td>Hypotension/DL number</td>
<td>0.45±0.5 ***</td>
<td>0.26±0.3</td>
<td>0.41±0.6</td>
<td>0.59±0.7</td>
</tr>
<tr>
<td>Δ Systolic BP %</td>
<td>21.5±11 *</td>
<td>17.6±10 *</td>
<td>20.6±13 *</td>
<td>23.8±13</td>
</tr>
<tr>
<td>Δ Diastolic BP %</td>
<td>16.0±8.1 *</td>
<td>12.6±7.7</td>
<td>15.3±9.5</td>
<td>17.0±9.3</td>
</tr>
<tr>
<td>Δ Mean BP %</td>
<td>18.8±9.3 *</td>
<td>15.2±8.8</td>
<td>18.0±11</td>
<td>20.5±11</td>
</tr>
<tr>
<td>DL, with NaCl bolus % frequency</td>
<td>26.62 **</td>
<td>18.12 ***</td>
<td>30.00 *</td>
<td>34.34</td>
</tr>
<tr>
<td>NaCl bolus number/DL</td>
<td>0.46±0.6</td>
<td>0.27±0.4</td>
<td>0.48±0.6</td>
<td>0.60±0.7</td>
</tr>
<tr>
<td>Pre-dialysis BWT kg</td>
<td>58.3±13</td>
<td>58.4±13</td>
<td>58.2±13</td>
<td>56.8±12</td>
</tr>
<tr>
<td>Post-dialysis BWT kg</td>
<td>56.4±12.5</td>
<td>56.4±13</td>
<td>56.1±13</td>
<td>54.6±12</td>
</tr>
<tr>
<td>Δ BWT/hr %</td>
<td>1.03±0.5</td>
<td>1.04±0.5</td>
<td>1.07±0.5</td>
<td>1.09±0.5</td>
</tr>
<tr>
<td>Pre-dialysis mean BP</td>
<td>113±13</td>
<td>115±13</td>
<td>115±13</td>
<td>113±11</td>
</tr>
</tbody>
</table>

*** p<0.001  
**  p<0.01  
*   p<0.05  
DL=dialysis

or the need to prolong the experience.

It is also possible to show the presence or the absence of factors influencing correct evaluation (that is variation of body weight, of hourly ultrafiltration, pre-dialysis blood pressure etc.

As an example we performed a prospective study, not double blind, of the value of substituting bicarbonate for acetate to reduce dialysis hypotension. We concluded that, in a standard dialysis schedule with a dialysate sodium of 140mmol/L, a short-term substitution of bicarbonate in place of acetate
significantly reduces the dialysis hypotension, but that when long-term periods are examined the improvement remains constant in a very few patients (2 out of 16). Therefore a 'placebo' effect cannot be excluded.

Acknowledgments

The authors gratefully acknowledge the secretarial assistance of Miss Laura Pesci.

References

1 Stead WW. Kidney Int 1983; 24: 436
2 Friedman EA. Am J Kidney Dis 1982; 2: 289
3 Kjellstrand C. Controv Nephrol 1980; 2: 12
7 Rosa AA, Fryd DS, Kjellstrand CM. Arch Int Med 1980, 140: 804
8 Woodward RH, Goldsmith PL. Cumulative Sum Techniques. Edinburgh: Oliver and Boyd. 1964