Teaching and training acute renal replacement therapy in children

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Abstract

Background. The objective of this study is to describe and analyse the initial experience in paediatric acute renal replacement therapy (ARRT) education by means of specific courses.

Methods. Three paediatric ARRT courses were run. The course programme included initial and final multiple-choice question (MCQ) exams, short lectures, practical workshops [in vitro peritoneal dialysis (PD) and continuous renal replacement therapy (CRRT) machines skill stations, real-time PD and CRRT in paediatric animal models and paediatric CRRT advanced simulation scenarios based on real cases) and an anonymous survey on the perceived value of the course (score from 0: very bad to 10: perfect). Number of students per workshop was six to eight. Continuous assessment of participants’ performance was done.

Results. In the initial MCQ, only 11% of students answered correctly at least 70% of questions, while in the final test, 90.5% hit this target (P < 0.001). In the performance assessments, all of the students demonstrated sufficient acquisition of practical skills. In the perceived value survey, the course methodology was rated at 9.3, organization 9.9, teaching staff 9.6, lectures 9 and practical sessions 9.1.

Conclusions. Specifically designed CRRT and PD courses are adequate for teaching the theoretical aspects and training these procedures. The combination of laboratory, training with animals and advanced simulation scenarios might have a synergistic effect on learning.

Keywords: children; continuous renal replacement therapy; medical education; peritoneal dialysis; simulation

Introduction

Acute renal replacement therapy (ARRT) by venous continuous renal replacement therapy (CRRT) and peritoneal dialysis (PD) are the most frequent techniques used for artificial renal support in paediatric and neonatal intensive care units (ICUs) [1–4]. They may be considered as essential procedures that must be available and performed safely and with efficacy in every ICU.

ARRT uses to be performed by the intensive care, neonatology and/or nephrology teams, depending of the organization of the ICU and hospitals [5–8].

In many hospitals, ARRT in children is not performed very frequently and physicians and nurses are not sufficiently trained in these techniques.

Renal replacement is generally taught in a relatively un-systematic unstructured manner, most centres lacking a specific training programme [9, 10]. To our knowledge, there are neither studies that have analysed the staff’s theoretical knowledge and practical abilities to use ARRT, nor is there any published methodology for training these techniques.

We developed a model of a theoretical and practical course in paediatric and neonatal ARRT, combining several teaching and training methodologies, that include lectures, in vitro models workshops, paediatric animal models and specifically designed advanced paediatric simulation scenarios. The main objectives of this course are the acquisition of theoretical knowledge and essentially, practical skills, to apply safely and effectively the ARRT modes in different clinical situations in children. The specific teaching goals were that after completion of the course, the trainee is able to indicate and prescribe the specific parameters of acute PD and CRRT in children, to modify the parameters according to the clinical situation and to identify problems and solve complications and alarms.

The aim of this study is to describe the methodology and evaluate the results of our initial experience.

Materials and methods

Between 2008 and 2010, three paediatric ARRT courses were run in two hospitals in Spain, aimed at paediatricians, intensive care paediatricians, neonatologists, resident doctors in paediatrics and paediatric critical care nurses from different cities of Spain and other countries.

The ARRT courses’s duration ranged between 18 and 26 h, spread >2–3 days. The number of students per course fluctuated between 21 and 24 and the number of instructors between X and Y. The course time was distributed as follows: theoretical lectures 25%, practical training 67% and MCQ assessment 8%. The course programme is displayed in Table 1.
The practical sessions included:

1. **Initial MCQ test**
2. **Renal replacement therapy: concepts and types:** haemodialysis, PD and CRRT
3. **PD**
4. **Haemodialysis**
5. **CRRT technique: vascular access, catheters, circuits, fluids**
6. **Practical sessions: PD and CRRT machine and circuit preparation**
7. **Practical management of CRRT: initial setup**
8. **Anticoagulation methods**
9. **Others: control, nutrition and drugs during CRRT**
10. **Techniques:** plasmapheresis, albumin dialysis, CRRT and extracorporeal membrane oxygenation.
11. **Practical sessions: PD and CRRT with animals**
12. **Practical sessions: clinical workshop**
13. **Practical sessions: advanced simulation session on CRRT**
14. **Algorithms of ARRT**
15. **Final MCQ**
16. **Course survey completed by students**

### The laboratory workshops

The objective of the laboratory workshops is to teach the material for and train how to prepare the PD and CRRT systems. For PD, the PD-Paed System® (Fresenius, Lexington, MA), a manual- and gravity-based system for clinical PD in babies and small infants and automated PD devices (Freedom Cycler; Fresenius) and Serena® (Hospal, Spain) were used. For CRRT, the Prisma® and Prismaflex® (Hospal, Gambio, Spain) and fluid bags (to simulate a patient) were used.

The workshop methodology included a preliminary demonstration by the instructor of the components, needed material and basic functioning of the system (pumps, monitorization, alarms). Subsequently, each of the participants had to assemble and make the system ready to clinical use. This includes the initial programming of PD or CRRT, (depending on the workshop), the in vitro starting of the procedure (with fluid bags simulating the patient circulation) and a new explanation of the monitoring with simulation of alarms, recalling their meaning and the basic way to solve them.

### Paediatric animal model workshops

Their objective was the training of clinical indication, programming, starting, monitoring and problem solving of PD and CRRT carried out in animals. For PD, we used rabbits with a weight between 3 and 5 kg, and for CRRT, pigs with a weight between 8 and 30 kg were used. The experimental protocol was approved by the local Institutional Ethical Animal Investigation Committee. Animals were previously prepared. Initial anaesthesia was performed with intramuscular ketamine and atropine. Rabbits were maintained in spontaneous respiration with intravenous ketamine doses. Pigs were intubated and maintained with mechanical ventilation. Sedation and muscle relaxation with propofol, fentanyl and atracurium by continuous infusion are maintained throughout the procedure. Monitoring included electrocardiogram, peripheral oxygen saturation (Viscoconn® monitor; KGB, Madrid, Spain), central venous pressure by external jugular vein cannulation and blood pressure and cardiac output by means of a femoral arterial thermodilution system (PicCO®; Pulsion Medical Systems, Munich, Germany). CRRT was performed through a 6.5–8 Fr CRRT catheter located in femoral vein.

This workshop methodology included a preliminary explanation of the clinical case by the instructor. The participants were asked to analyse the clinical situation of the ‘patient’ (animals) and to evaluate the initial haemodynamics and the biochemical parameters. Subsequently, they had to programme the parameters of the technique (PD or CRRT), to initiate it, surveying the changes provoked in the animal’s haemodynamic parameters and to solve the problems that eventually occurred. The instructors organized the workshop to permit each student to participate in every part of the session. During the workshop, the instructors simulated problems that use to arise during clinical use of PD or CRRT, for example, limited effluent volume in PD or high pressures or presence of air in the system in CRRT.

### Advanced simulation scenarios

The specific objective was to train CRRT (initial setup, starting and real-time problem solving) in a simulated paediatric scenario (an infant with acute renal failure and hypervolaemia in the postoperative period of cardiac surgery). The Simbaby® (Laerdal, Norway) advanced simulation system was used. Due to the fact that Simbaby® lacks a ‘central venous system’ a CRRT catheter was fixed simulating a femoral central venous line with its distal end placed under the manikin and connected in line with the CRRT monitor Prismaflex® (Hospital). In order to permit the simulation of different pressures and generation of selective alarms in the CRRT monitor, a hand-made system consisting in prolongation of the lines and the placement of adjustable external clamps was prepared. After the initial brief of the case, the participants had to assess the clinical situation of the patient, to analyse the starting haemodynamic parameters and biochemical results and immediately decide and perform the renal replacement therapy. The initiation of CRRT and its management occurred in real-time during a maximum of 30 min, a period when typical clinical problems and changes in haemodynamics were provoked by the instructors. The general evolution of the scenario was programmed beforehand but the instructors introduced on the fly changes in that evolution, according to the participants’ performance. After the scenario, there was a 30-min debriefing supported by the video record of the simulation.

### Interactive clinical workshops

There were small group discussions about the indication of renal replacement therapies, the meaning of clinical signs and haemodynamic/biochemical parameters, advantages versus drawback of specific therapies, monitoring and problem-solving strategies in real or hypothetical cases. The material of the course and the specific methodology of the skill stations are shown in Supplementary annexes 1–5. Any complementary data can be obtained without limitations through contact with the main author (pilvi@hotmail.com).

Participants’ assessment. The theoretical tests included an initial and a final MCQ, consisting of 15 to 26 questions related to the essential learning topics of the programme. The cut-off to pass the test was placed at 70%. The questionnaire is shown in Supplementary annex 6. We also compared the results of the students in the MCQ with a comparable population that did not receive the training.

Practical performance assessment was done by instructors throughout the course considering the items and the score presented in Table 2.

Assessment of the course by the participants. At the end of the course, students were asked to anonymously rate all the aspects of the course by means of a scale from 0 (very bad) to 10 points (perfect). Items included organization, teaching staff, methodology, lectures, workshops, simulated scenarios and aspects to be improved in future courses.

Instructors met at the end of the course to discuss the theory and practice results of each student and to decide if they pass or fail the course.

Statistical analysis of the results was performed using the statistics programme SPSS 15.0. Student’s t-test was used for comparison between variables. Values of P < 0.05 were considered to represent statistically significant differences.

### Results

Three courses were imparted to 66 students, 56% of these were paediatricians, 9.5% staff of adult ICU or anaesthesia, 33% paediatrics or anaesthesia residents and 1.5% nephrology nurse.

In the initial MCQ test, the mean score was 5.0 ± 2.1 (range 1.3–9.3). Only 11.1% of the students were able to answer 70% of questions correctly. In the final MCQ test, the mean grade was 8.5 ± 1.0 (range 6–10). P < 0.001. Ninety per cent answered >70% of the questions correctly. The results in the MCQ in a comparable population of 20
residents, paediatric intensive care physician and nurses that did not received the training was 5.6/C6 1.7 (range 2.3–9.6).

There was no significant difference between the score in the MCQ test of this control group and the initial score of the students, but there was a significant difference with the final score of the students (P < 0.001).

There were significant differences in the score of the initial theoretical test between the residents (4.5) and the staff paediatricians, adult intensivists or anaesthesia doctors (6.5) (P < 0.01) but not in the final test (8.2 versus 8.7) (P = 0.3). Only a 14.3% of the residents and 37% of the senior physicians were able to correctly answer at least 70% of questions in the initial test, which compares with 81 and 100%, respectively, in the final test.

The results of the participants’ assessment of the course are summarized in Table 3. The different instructors as well as theoretical and practical sessions were equally rated by the students (P > 0.1). They found the course to be well suited to their training needs and declared a high level of satisfaction after the course.

**Discussion**

To our knowledge, this is the first study that describes a structured paediatric ARRT education programme and analyses the results of the three first courses. Our experience showed the efficacy of the collaboration between paediatric nephrologists and paediatric intensivists to perform paediatric ARRT training programmes.

The theoretical and practical programme covers the most important aspects related to ARRT, from basic knowledge of dialysis, programming PD and CRRT, monitoring the technique and solving the most frequent incidents and problems that use to arise in clinical practice.

We have chosen a fundamentally practical methodology. Workshops and simulations of significant clinical cases and the most relevant incidences that use to occur during ARRT in children constitute the core of the course. Students are required not only to indicate and start the technique but also to interpret the changes in the parameters/measurements and the alarms that are displayed by the device and the monitoring systems, in the same way as they would appear in real clinical practice. Training is also oriented to a safe and coordinated team management of ARRT [11].

Workshops lasts 90–180 min, which is sufficient time to develop their content, having in mind the small number of students (six to eight per group); this means that each one can participate several times in the procedures. The reduced size of the groups also favours communication with colleagues and the guided open discussions. We believe that this process is an essential aspect of the adult’s learning experience and contributes to clarifying concepts and reinforcing knowledge and skills.
Table 3. Results of the student satisfaction survey

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<tr>
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<th>Mean</th>
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<tbody>
<tr>
<td>Organization</td>
<td></td>
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<tr>
<td>Information</td>
<td>10</td>
</tr>
<tr>
<td>Documentation</td>
<td>7.5</td>
</tr>
<tr>
<td>Organization</td>
<td>9.9</td>
</tr>
<tr>
<td>Teaching material</td>
<td>9.6</td>
</tr>
<tr>
<td>Timetable</td>
<td>90.6% adequate</td>
</tr>
<tr>
<td>Number of students</td>
<td>94% adequate</td>
</tr>
<tr>
<td>Teaching staff</td>
<td></td>
</tr>
<tr>
<td>Knowledge of the topic and capacity for teaching</td>
<td>9.6</td>
</tr>
<tr>
<td>Theoretical and practical coordination</td>
<td>9.4</td>
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<tr>
<td>Coordination between professors</td>
<td>9.1</td>
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<tr>
<td>Methodology</td>
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<tr>
<td>Fulfilment of objectives</td>
<td>9.6</td>
</tr>
<tr>
<td>Methodology</td>
<td>9.3</td>
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<tr>
<td>Theoretical classes</td>
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<tr>
<td>ARRT: concepts and types</td>
<td>9.2</td>
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<tr>
<td>PD</td>
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<td>Haemodialysis</td>
<td>8.3</td>
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<tr>
<td>Vascular access, catheters and circuits</td>
<td>9.3</td>
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<tr>
<td>Practical programmation of CRRT</td>
<td>9.6</td>
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<tr>
<td>Anticoagulation, drugs and nutrition</td>
<td>8.8</td>
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<tr>
<td>Other CRRT techniques</td>
<td>9</td>
</tr>
<tr>
<td>ARRT algorithms</td>
<td>9</td>
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<tr>
<td>Practical classes</td>
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</tr>
<tr>
<td>PD technique</td>
<td>9.1</td>
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<tr>
<td>CRRT technique</td>
<td>9.3</td>
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<tr>
<td>PD in animals</td>
<td>9.4</td>
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<tr>
<td>CRRT in animals</td>
<td>9.5</td>
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<tr>
<td>Advanced simulation CRRT</td>
<td>8.4</td>
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<tr>
<td>Clinical cases discussion</td>
<td>8.8</td>
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</table>

In order to obtain the advantage of each of them, we decided to include in the course diverse teaching methods, from lectures, clinical workshops, in vitro workshops, animal practical stations and advanced simulation.

Simulation is showing to be an excellent training method, making it possible to learn and acquire skills in a controlled, safe environment as similar as possible to clinical practice, with opportunities for repetition and debriefing and with students being active participants in both the learning and assessment processes [12–17]. Our experience confirms that advanced simulation is also useful for ARRT training and that it is possible to adapt the commercial paediatric manikins and CRRT systems with relatively simply modifications to simulate a realistic ARRT scenario. The ideal situation would be that all practical stations performed in the animal could be substituted by practical stations using advanced simulation with manikins and in our opinion that is the future. However, currently and in our experience, it is not possible to simulate adequately with sufficient realism all situations in the simulation laboratory and therefore animals are irreplaceable.

The results of our course confirm that structured theoretical/practical courses that combined several types of practical stations are an adequate method for training health care professionals responsible for ARRT in children. These results concord with the findings of cardiopulmonary resuscitation and mechanical ventilation courses, which use similar methodology [18, 19] and confirm the usefulness of teaching methods focused on acquiring practical skills and based on problem solving rather than on theoretical knowledge [13, 20–23].

Although the comparison of the participants, before and after the course, is the best way to evaluate the efficacy of the course, we also have compared the results with a control comparable population that did not receive the training. The results of this control group were similar to the initial MCQ scores of the students. These figures validate the educational efficacy of the course. The initial MCQ test gives us an idea of the students’ prior level of knowledge and, by comparing this with the results of the final test, allows us to evaluate the level of improvement made during the course. Our tests included questions oriented to clinical cases and problems and only 11% of students attained the minimum pass level at the beginning of the course. This may be due to a lack of theoretical knowledge and/or to difficulties in using theoretical knowledge to answer questions that may arise in clinical practice. In contrast, in the final MCQ test, 90% of students passed (they correctly answered >70% of questions), a result that demonstrates the effectiveness of the training programme.

Although we found statistically significant differences when compared with the results of residents and staff physicians in the initial MCQ, we observed that 63% of senior physicians did not have an adequate initial theoretical knowledge. This figure suggests that even doctors who perform ARRT in daily practice may lack some important knowledge on the subject. On the other hand, we consider positive the fact that at the end of the course, both residents and staff physicians achieve similar results with a high percentage surpassing the 70% cut-off level.

The evaluation of the course by the students showed a high level of satisfaction in all aspects analysed, whether organization and methodology or theoretical and practical sessions, suggesting that this type of training is well accepted by the health professionals. The lack of significant differences in the evaluation of the different theoretical and practical sessions suggests that the methodology used by the various teachers throughout the course was homogeneous or comparable. In order to facilitate this aspect, we consider it essential to train the trainers by means of specific instructor courses.

Although we have not done a cost analysis, it is clear that courses like these, with high student/instructor ratio and several practical sessions that need expensive materials, have a high cost per student. This fact must be remarked when similar initiatives will be considered.

Our study has some limitations. Results derive from three pilot courses with a not strictly homogeneous programme and contents; therefore, they should be considered as preliminary. Although the theoretical assessment was designed by drawing on information taught in the course, the test was not validated and the chosen level of 70% as a limit for determining sufficient knowledge was arbitrary, based on experience in other courses.

The courses did not include one specific session for the evaluation of each individual. The evaluation of the practical skills throughout the course may lack specificity and it is probably better to use a specific objective structured clinical examination. This station would permit a more detailed and specific assessment of the performance of each student,
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although the duration of the course will increase. In fact, we are implementing this kind of final practical evaluation station for the next courses.

It must be recognized that assessment of practical skills and attitudes involve a subjective component, which is extremely difficult to eliminate. In order to limit this bias, at the end of the course, instructors discussed the performances of students with deficiencies in order to better evaluate their training.

Our study did not analyse if the theoretical knowledge and practical skills can be maintained over time. This is a very important fact that must be analysed to evaluate the real usefulness of the training and the need for refresher courses. However, our participants came from many cities in Spain and from other countries as well, a fact that makes it very hard to join them again some time later in order to analyse their theoretical knowledge and practical skills in a simulated scenario.

We conclude that ARRT courses are an adequate method for training health professionals in paediatric ARRT.

Supplementary data

Supplementary data are available online at http://ndt.oxfordjournals.org.

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