Clinical experience with VIE-PNN, a knowledge-based system for planning the parenteral nutrition of newborn infants.

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Abstract

Background: Knowledge-based systems are rarely used in the clinical routine. VIE-PNN, an interactive knowledge-based system, has been integrated in the local network of our patient data management system and used at the bedside since more than two years.

Objective: To evaluate the performance and acceptance of a routinely used knowledge-based system.

Methodology: Based on a few input data and the expert defined prescription rules, VIE-PNN calculates and displays suggestions for the components of parenteral nutrition solutions (PNS). These suggestions may interactively be changed by the prescribing physicians if considered necessary. For patients with partial enteral nutrition, the PNS components are reduced according to the ratio of parenteral/enteral fluid supply.

We prospectively analyzed 50 PNS calculated in parallel by VIE-PNN and manually (MAN), i.e. by using a hand held calculator. We retrospectively analyzed 5539 PNS stored in the system's database and evaluated a questionnaire asking physicians about their experience with VIE-PNN.

Results: The mean time needed for calculating a PNS was 2.4 (VIE-PNN) vs. 7.1 minutes (MAN) corresponding to daily time savings of about 3/4 hour for 10 PNS calculations. Expert review detected errors or omissions in 22% (VIE-PNN) vs. 56% (MAN) of the PNS prescriptions. All errors in the VIE-PNN based PNS were related to interactively changed values. Analyzing the 5539 stored PNS, 4 of 16 parameters were interactively changed by the prescribing physician. The questionnaires showed a good overall acceptance of VIE-PNN. Time savings and improvement of precision were rated as equally important benefits.

Conclusion: We conclude that the use of our knowledge-based system for PNS prescription led to important time savings and improvement of precision.

Key Words: Knowledge-based system, clinical evaluation

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Introduction

Prescribing parenteral nutrition solutions (PNS) is time consuming tedious routine work at neonatal intensive care units (NICUs) needing expert knowledge and experience. Potentially dangerous errors and omissions are, however, virtually inevitable (1,2). Hand held calculators have reduced the time load associated with PNS calculations, and since computers are more commonly available, more or less complex computer programs have been designed in order to assist clinicians in their daily routine: Baker et al. (3) were the first to describe a simple program for calculating or reviewing PNS, other authors used spreadsheet technology (4) or nutrition tables (5) as simple but efficient solutions to avoid errors and time consuming calculations. More complicated rule and knowledge-based systems (6-9) have been designed to further decrease the workload and to provide a problem oriented approach to PNS prescriptions including the handling of pathological conditions. More recently, this focus was extended to more sophisticated problems such as optimizing calcium and phosphorus prescription in VLBW infants (10). Clinical evaluation of programs for prescribing PNS showed that optimizing nutrient supply (11), reducing routine work load (11-13) and avoiding errors (14) are measurable benefits in short term evaluations.

Although knowledge-based systems offer obvious advantages, these systems have only rarely found their way into the clinical routine. Developing VIE-PNN (7,8), our knowledge-based system for calculating PNS of newborn infants, we found that the system was only accepted by clinicians if there was a clear time saving benefit: despite improvements in precision and readability of PNS prescriptions, VIE-PNN was not routinely used until a redesign (15) made the system available at the bedside and faster in prescribing a PNS than calculating (or copying) it by hand. Using VIE-PNN at our NICU since a period of more than two years, we were interested if the subjective benefits could be quantified. We therefore prospectively and retrospectively evaluated VIE-PNN in order to find out the amount of daily time savings, of errors and omissions occurring in the routine use and the overall acceptance of a knowledge-based system.

Methods

Program description of VIE-PNN

VIE-PNN (version 5) is a modular client-server program based on the Hypertext Markup Language (HTML) and CGI (Common Gateway Interface) PERL (Practical Extraction and Report Language) programs (15). It consists of three modules, 1. a main module for calculating the PNS prescriptions, 2. a patient administration and data base module for adding, updating and storing patient data, and 3. a maintenance module for editing and updating rules, nutrition components, rounding factors and value ranges. The system's knowledge base is coded in simple PERL-like IF-THEN rules which can be edited by an authorized expert. VIE-PNN is integrated in the intranet of the local patient data management system (PDMS) and can be used at all bedside terminals.

For calculating a PNS prescription, eight interactive HTML pages have to be verified and completed. Manual input includes patient data, actual weight, fluid supply, type and amount of enteral nutrition, type of venous access, lab values (if available), bypass medication, and presence of relevant clinical problems like respiratory distress (carnitine and inositol are added for newborn infants weighing less than 1500g), cholestasis (less amino acids), sepsis (less fat) or inappropriate ADH secretion (fluid restriction and no sodium replacement). Unchanged or default values have only to be confirmed.

The daily supply of electrolytes, amino acids, fat, additives (vitamins, trace elements, carnitine), bypass medication and glucose is then calculated and displayed according to the

rules contained in the knowledge base. The suggested individual values can than either be accepted or interactively changed. An information button opens an explanation page for reviewing the specific calculation algorithm. The complete PNS prescription can be checked on the last screen and then printed out.

Clinical evaluation

The clinical evaluation of VIE-PNN comprised three parts: prospective evaluation of PNS prescriptions, retrospective evaluation of stored PNS prescriptions, and evaluation of a questionnaire distributed to the neonatologists using the system.

We prospectively evaluated 50 routine PNS prescriptions for newborn infants admitted to one of our two NICUs. The PNS were calculated in parallel by various physicians in charge, one using VIE-PNN, and another a hand held calculator (manual calculation, MAN). We compared: the time needed for calculating a PNS prescription and the differences in the amount of PNS components exceeding more than 1 unit (e.g. 1 mmol/kg Na, 0.5 g/kg amino acids). Both PNS sheets were later reviewed by a senior neonatologist. Errors or omissions were rated as potentially life threatening (e.g. prescribing >6 mmol/kg/d potassium or a dangerous concentration of bypass medication), as major, i.e. clinically important but not life threatening (e.g. prescribing too little amounts of Ca), or as minor, i.e. clinically not relevant (e.g. forgetting to calculate the total energy supply).

We retrospectively evaluated the routine PNS prescriptions stored in VIE-PNN's database between July 1996 and July 1998 for the number of interactively changed values of VIE-PNN suggestions and for the computer contact time (CCT), i.e. the time from the begin of interactive data input to sending the print command for an individual PNS. The CCT is not equal to the time needed for the calculation of a PNS because physicians are often distracted from prescribing PNS, e.g. being called at the bedside or for answering questions at the telephone.

We also tracked the program's updates performed during the evaluation period in order to quantify the work needed for program maintenance.

Finally, we evaluated a users questionnaire (Table 1) answered by the neonatologists of our two NICUs.

Table 1. Questionnaire for subjective evaluation of VIE-PNN.

1. Rate your degree of satisfaction with VIE-PNN:
   1-2-3-4-5 (1-very satisfied - 5-not at all satisfied)
2. Please How often do you use VIE-PNN in the daily routine:
   1-2-3-4-5 (1-daily - 5-never)
3. Why do you use VIE-PNN (multiple answers possible):
   because VIE-PNN
   1 - enables time savings
   2 - improves the accuracy of the PNS prescriptions
   3 - facilitates PNS calculation
   4 - produces a better readable printout
   5 - other reasons
4. Which one of the five answers in question 3 do you rate most important:
   1-2-3-4-5
5. What could/ should be improved in VIE-PNN (free text answers)

Statistical methods

Statistical analysis comprised descriptive statistics and paired t-test analysis. Differences were considered significant at the 5% level.

Results

Prospective evaluation of the PNS prescriptions

Using VIE-PNN resulted in significant ($p < 0.001$) time savings of a mean of 4.7 minutes per PNS prescription. The mean time needed for a prescription was 2.4 minutes (± 0.8 (SD), range 1-4 minutes) for VIE-PNN and 7.1 minutes (±3.3 (SD), range 3-16 minutes) for manually calculated (MAN) prescriptions. This sums up to about 1/2-1 hour daily time savings for the 8-12 PNS prescriptions prepared at each of our two NICUs.

There were only little and no systematic differences in the composition of the PNS: less or more glucose (12/50), amino acids (8/50) or electrolytes (8/50).

The expert neonatologist found no life threatening errors in the 50 PNS prescriptions. There were less major (10% (VIE-PNN) vs. 18% (MAN)) and minor (12% vs. 66%) errors and omissions in the VIE-PNN calculated prescriptions. Major errors were related to the prescription of glucose (0 vs. 10%), electrolytes (10% vs. 6%) or bypass medication (0 vs. 2%). Minor errors were related to the prescription of glucose (0 vs. 14%), fat (6% vs. 2%), electrolytes (0 vs. 16%), vitamins (6% vs. 6%) and to forgetting to calculate the energy content of the PNS (0 vs. 28%). All errors in the VIE-PNN assisted prescriptions were detected in values changed interactively by the prescribing physician.

Retrospective evaluation of PNS prescriptions

Retrospective evaluation of 5593 stored PNS prescriptions of 643 patients showed that a mean of four out of 16 parameters were interactively modified by the physicians. The median computer contact time, i.e. the time from the begin of interactive data input to sending the print command for an individual PNS amounted to 5.7 (range 1-371) min.

Throughout the study period of 24 months, the prescription rules of virtually all PNS components were revised or changed for clinical reasons: major modifications comprised the rules for prescribing electrolytes, amino acids and protein, fat and glucose, minor modifications comprised rounding factors, new bypass medication and new brands of oral nutrition products.

Evaluation of the users questionnaire

Evaluation of the 11 users questionnaires showed that the mean rating for satisfaction with VIE-PNN was good (1.9/5). VIE-PNN was routinely used for the following reasons: time savings: 73%, improvement of accuracy: 73%, less calculation effort 64%, better readable printout 45%. Time savings and improvement of accuracy were rated equally important.

Discussion

VIE-PNN, our knowledge-based system for calculating PNS of newborn infants, was well accepted by the users, reduced the time needed for prescribing PNS and improved the precision of the prescriptions. Moreover, for a clinical evaluation period of about two years there were no disadvantages or systematic problems associated with the routine use of our knowledge-based system.

Our findings are according to the results of other studies describing significant reductions in association with computer assisted PNS prescriptions: 3-13 minutes time savings (11-13,16,17) and reduction of errors and omissions (14).

VIE-PNN's main advantages are founded on its rule-based algorithm mirroring the clinical reasoning process and including enteral and parenteral nutrition support. Moreover, integrated features such as automated increase of daily nutrition supply, checks for consistency and completeness, automated rounding of individual supplies, and rules for

specific clinical conditions such as fluid restriction, cholestasis or inappropriate ADH secretion guide the user in maintaining a high standard of neonatal nutrition management. The program's interface, a standard web browser, requires only minimum training even for physicians who are not experienced in using computers.

A practical feature of VIE-PNN is its explanation capabilities: all calculations can immediately be reviewed in detail. This helped the developers in explaining the reasoning process of the program to the users and in finding rule implementation errors. It also helped experienced users in improving confidence in the system and less experienced users to use VIE-PNN as a tutorial guideline for improving their skills.

PNS composed by VIE-PNN were very similar to the manual calculations. This is mainly due to the fact that VIE-PNN's rules exactly follow the relatively strict clinical reasoning process routinely used at our NICUs (7,8,15). This improved the local acceptance of our system but did not improve the contents of the PNS as has been suggested by other authors (11,16).

The number of errors detected in the VIE-PNN and the manually calculated PNS was relatively high with major errors and omissions of 10% vs. 18% and minor errors and omissions of 12% vs. 66% (or 38% if omitting to calculate the energy content is not counted). It however reflects the clinical experience and the importance of a computer system for improving the quality of the prescriptions. Moreover, as all errors in the VIE-PNN based prescriptions were related to interactively changed values, human imperfection remains the most important but irreplaceable source of errors.

Retrospective evaluation of VIE-PNN showed a good acceptance of the system. All users preferred VIE-PNN to manual calculation. The relatively high number of interactively changed values (1/4) is partly due to the fact that electrolytes were not automatically imported from the lab computer and that some colleagues preferred to interactively change the electrolyte supply instead of typing in lab values. This underlines the necessity of integrating as much automated data input as possible in such applications. On the other hand, VIE-PNN covers a lot but not all possible clinical problems that may need more individualized PNS prescriptions.

The median time of computer contact of 5.7 minutes does not reflect the time spent with the calculation of PNS because physicians are often distracted from PNS prescriptions for clinical reasons, telephone calls, etc. The contact time was, however, smaller than the mean time needed for manual calculations in our 50 PNS samples.

VIE-PNN had to be adapted during the observation period mostly because of small inconveniences, rounding problems, distributing glucose to two different strengths of solution, a revised policy of adding plasma proteins to the PNS, introducing new nutritional products, etc. The need for changes followed the rule, the better a program the higher the user's expectations and the poorer the tolerance of inconveniences (18).

Evaluation of the questionnaire reflects the good acceptance of VIE-PNN because of its time saving and error avoiding properties. There was, however, a list of desirable amendments and changes such as implementation of new rules for vitamin and calcium prescription in extreme low birth weight infants, increase of the number of possible bypass medication (presently five), etc. This again reflects that clinically used knowledge-based systems are never static but need frequent minor and major revisions in order to keep pace with the clinical needs and the evolution of clinical knowledge. Minor revisions are supported by VIE-PNN, namely by its maintenance module.

We conclude that our knowledge-based system, VIE-PNN, was very suitable in saving time and improving efficacy in the clinical routine of PNS prescribing. The program is a "living" system and has to be adapted to the changing clinical needs. Further enhancements like graphical data visualization and more precise integration of enteral nutrition supply will possibly further enhance its benefits.

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