

Provider Error Prevention: Online Total Parenteral Nutrition Calculator

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Experience is that marvelous thing that enables you to recognize a mistake when you make it again.

Franklin P. Jon

Abstract:

Objective: 1. To reduce errors in the ordering of total parenteral nutrition (TPN) in the Newborn Intensive Care Unit (NICU) at the Johns Hopkins Hospital (JHH). 2. To develop a pragmatic low-cost medical information system to achieve this goal.

Methods: We designed an online total parenteral nutrition order entry system (TPNCalculator) using Internet technologies. Total development time was three weeks. Utilization, impact on medical errors and user satisfaction were evaluated.

Results: During the control period, 0.39 orders per patient per day (N=557) were received compared to 0.35 orders per patient per day (N=471) in the intervention period (NS). There was no significant difference in the percentage of late (incomplete by order deadline) TPN orders. During the control

period, an average of 10.8 errors were detected per 100 TPN orders compared to 4.2 per 100 orders in the intervention period (61% reduction of error rate; $p < 0.01$). We found a reduction in the following types of problems: Calculation errors (100%), osmolality issues (87%) and other knowledge problems (84%). There was a 35% increase in the number of incomplete forms. Users of the system were enthusiastic and supportive and compared it favorably to the prior paper based system.

Conclusion: Low-cost, pragmatic approaches utilizing Internet technology in the design of medical information systems can reduce medical errors and might pose a viable option for the prevention of adverse drug events.

Introduction:

According to an estimate by the Institute of Medicine in 1999, more than one million injuries and almost 100,000 deaths must be attributed to medical errors annually.¹ Most errors that occur in the prescription,

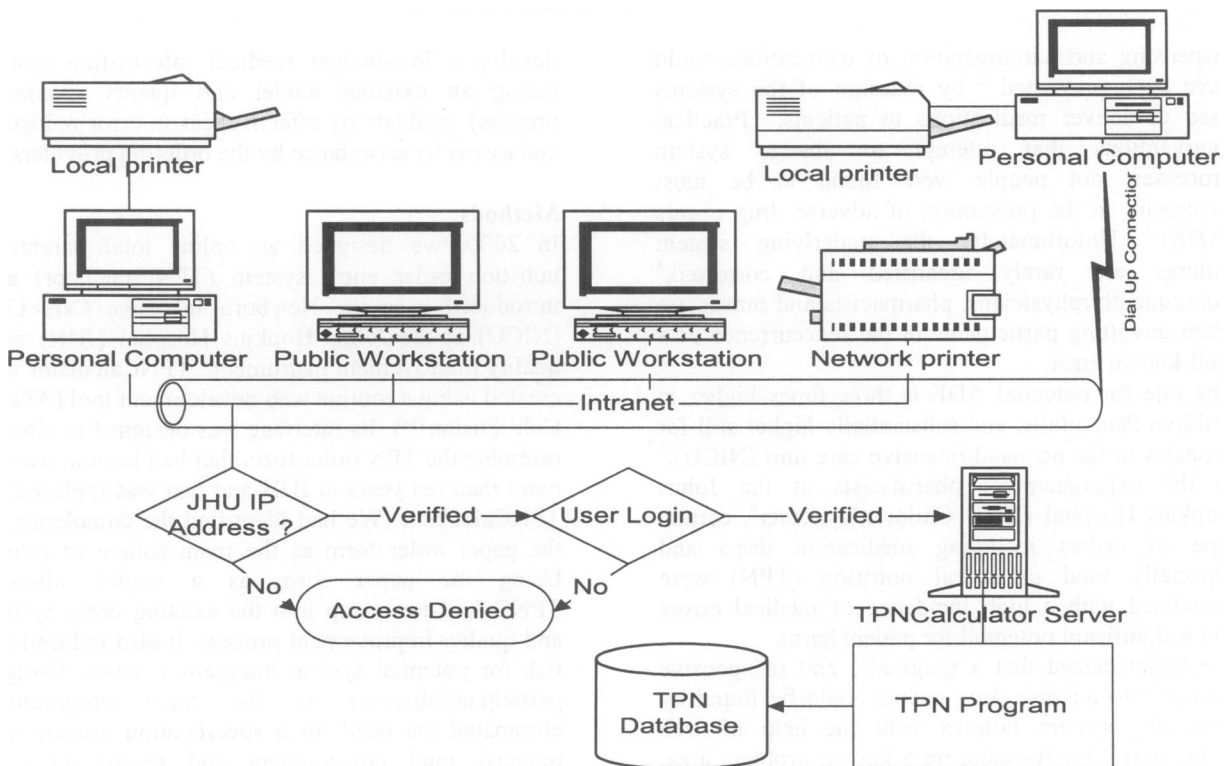


Figure 1. TPNCalculator system elements

The screenshot displays the TPN Calculator interface with the following components:

- Electrolyte Inputs:**
 - Sodium: 6 mEq/kg * 1.350 kg = 8.1 mEq
 - Potassium: 2 mEq/kg * 1.350 kg = 2.7 mEq
 - Magnesium: 0.5 mEq/kg * 1.350 kg = 0.68 mEq
- ADDITIVES:**
 - For other Additives (Vt K, Albumin, Camitine) check here and press recalculate:
 - Calcium: Super Max Max Standard None Max Calcium
 - Phosphate: Super Max Max Standard None Standard Phosphate
 - Anions: 60% Chloride - 40% Acetate (dropdown) 60% Chloride - 40% Acetate
 - Multivitamins: Yes No None
 - Trace Elements: Yes No Standard
 - Heparin: 0.5 units/ml 0.5 units/ml
 - Ranitidine: 2 mg/kg/day * 1.350 kg = 2.7 mg/day Ranitidine
- ADDITIVES / INSTRUCTIONS:** A large empty text area for notes.
- Alerts and Reminders:**
 - Press here for Dosing Guidelines
 - !Alert! Are you sure you don't want to add MultiVitamins?
 - !WARNING! Heparin not recommended with PERIPHERAL Access.
 - !WARNING! Total Osmolality is 1153.6
- Buttons:** RECALCULATE and FINALIZE

Figure 2: TPN Calculator Screenshot. Note rule-based alerts and reminders.

dispensing and administration of medications could have been prevented² by redesign of the systems used to deliver medications to patients. Practical interventions that attempt to change system processes, not people were found to be most successful in the prevention of adverse drug events (ADE).³ Unfortunately, the underlying system failures are rarely identified and corrected.⁴ Subsequently physicians, pharmacists and nurses are often unwitting participants in the reoccurrence of a well-known error.

The rate for potential ADE is three times higher in children than adults, and substantially higher still for neonates in the neonatal intensive care unit (NICU).⁵ In the experience of pharmacists at the Johns Hopkins Hospital (JHH) Children's Center⁶, certain type of orders including medication drips and especially total parenteral nutrition (TPN) were associated with a high incidence of medical errors and a significant potential for patient harm.

We hypothesized that a pragmatic and inexpensive approach to adverse drug events could be found by correcting system failures with the help of web technology. By focusing on a known problem area, the ordering of parenteral nutrition, we aimed to

develop a low-budget medical information system (using an existing model and quality assurance process), evaluate its effectiveness in error reduction and assess its acceptance by the ordering providers.

Methods:

In 2000, we designed an online total parenteral nutrition order entry system (TPN Calculator) and introduced it in the Newborn Intensive Care Unit (NICU) at the Johns Hopkins Hospital (JHH) as a quality improvement instrument. TPN Calculator was created using a routine web development tool (Allaire Cold Fusion™). Its interface was designed to closely resemble the TPN order form that had been in use for more than ten years at JHH and that was replaced by TPN Calculator. We had identified the completion of the paper order form as the main source of errors. Using the paper form as a model, allowed TPN Calculator to tap into the existing order system and quality improvement process. It also reduced the risk for potential system integration issues. Using a participant/observer as the main programmer eliminated the need for a specification process and reduced total development and testing time to approximately three weeks.

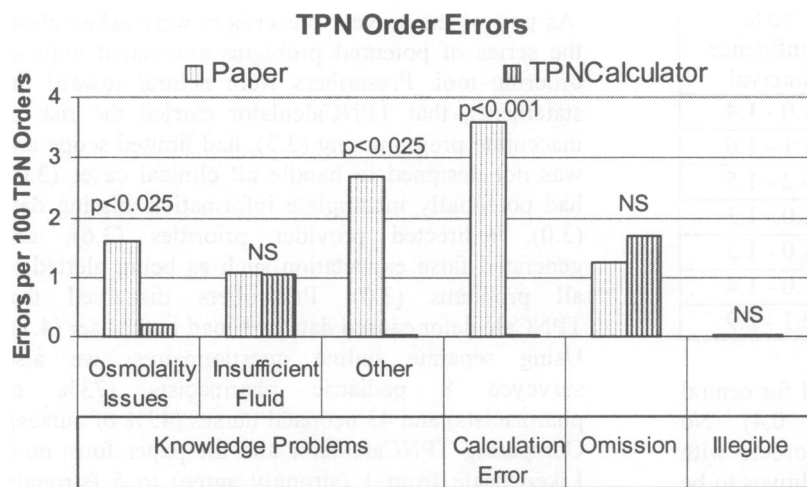


Figure 3: Error Distribution

Through a public workstation or a desktop computer (Figure 1), the user (resident, nurse practitioner, pharmacist, nutritionist) accesses the TPN Calculator using individual login identification and password. All interactions between the TPN Calculator Server and the user's browser are 128-bit encrypted to be Health Insurance Portability and Accountability Act compliant.

The user may select to enter a TPN Order for a new patient, or modify/renew an old order for an existing patient. TPN Calculator performs all necessary fluid and component calculations based on provider input via an Internet browser. It contains nutritional guidelines, an osmolality calculator and 62 rule-based alerts and reminders (Figure 2).

Residents received a brief 10-minute training prior to the initial use of the TPN Calculator.

Data collected included the number of parenteral

nutrition orders and the frequency and type of errors as identified by the pharmacist. Data were collected during a control period (10/2/2000 - 11/14/2000) immediately prior and during an intervention period after (11/15/2000 - 12/31/2000) the implementation of an online total parenteral nutrition order entry system (TPN Calculator). Prescribers, pharmacists and nurses were surveyed online on their experiences and opinions in the course of using TPN Calculator.

Results:

During the control period, average patient census was 32.3. During this time 557 TPN orders were written compared to 471 orders in the intervention period (average census 30.2). The number of TPN orders per patient per day was not significantly different between the two time periods (control: 0.39 orders per patient per day - intervention: 0.35 orders per patient per day). During both time periods only half the orders were available to the pharmacy by order deadline at noon (51.7% control, 48.6% intervention). During the control period, prescribers most commonly cited lack of time as the cause for the delay (86%). While this was also the most common cause during the intervention period (54%), reduced staff during the holidays was also given as a frequent cause (31%).

During the control period, a total of 60 errors that required the pharmacist to contact the provider were detected compared to only 20 errors in the intervention period. This translated to an average of 10.8 errors per 100 TPN orders during the control period compared to 4.2 per 100 orders in the intervention period (61% reduction in error rate; p < 0.01).

Error type distribution was significantly different between the two groups (Figure 3). During the use of the paper form (control period), prescribers were significantly more likely to order fluids, which exceeded the osmolality guidelines (Control 1.6, Intervention 0.2 per 100 orders), make calculation errors (Control 3.6, Intervention 0 per 100 orders), and generate orders that demonstrated other knowledge

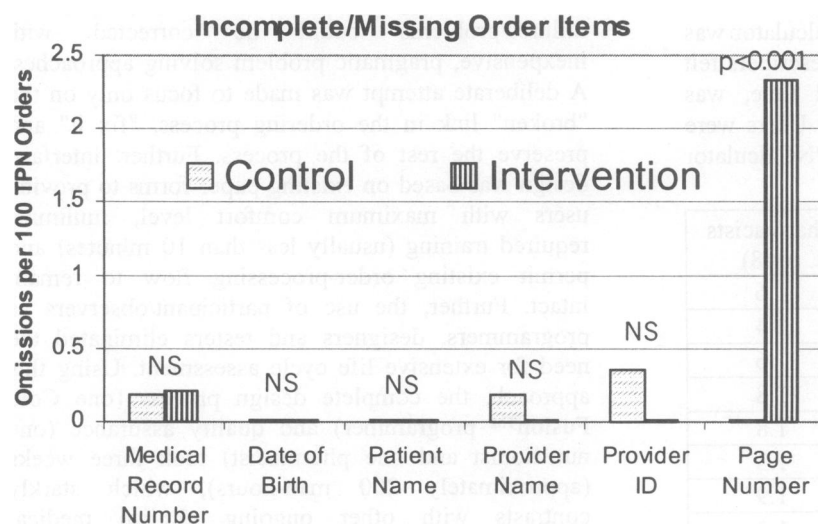


Figure 4: Incomplete Orders

Table 1: Prescriber Survey (N=28)	Average Rating	95% Confidence Interval
Easy to use	1.2	1.0 - 1.4
Easy to learn	1.3	1.1 - 1.6
Protects against errors	1.3	1.2 - 1.5
Saves time	1.1	1.0 - 1.3
Helpful	1.2	1.0 - 1.3
Improvement	1.2	1.0 - 1.4
Better learning experience	2.5	2.1 - 2.9

deficiencies (example: no heparin ordered for central line TPN) (Control 2.7, Intervention 0.4). No difference was noted in the number of orders with insufficient fluid amounts to allow all additives to be dissolved. There was an increase from 1.7 incomplete orders per 100 TPN orders in the control period to 2.3 in the intervention period (NS). Omission of the page number on the order form (order identifier) contributed to 92% of all incomplete orders in the intervention period (Figure 4).

After a six-month period, when all stakeholders had an opportunity to interact with the TPNCalculator; 84 providers, nurses and pharmacists were surveyed using an online questionnaire.

We surveyed 28 prescribers including 22 PGY-1 residents (100% of interns) and 6 neonatal nurse practitioners (100% of neonatal nurse practitioners). Seven percent (7%) had used TPNCalculator less than 5 times per week, 21% 5-9 times, 36% 10-19 times and 36% more than 20 times per week. On a scale from 1 (very easy) to 5 (very difficult), TPNCalculator was rated 1.5. On a Likert scale (1=strongly agree, 3 = neutral, 5 = strongly disagree), prescribers were asked to compare the TPNCalculator to the paper form (Table 1).

In comparison to the paper form, TPNCalculator was found to be easier to learn and to use. Prescribers felt that it protected against errors, saved time, was helpful and constituted an improvement. Users were neutral to the statement that the TPNCalculator provided a better learning experience.

Table 2: Nurse/Pharmacist Survey	Nurses (n=43)	Pharmacists (n=8)
Easier to read	1.7	1.6
Easy to learn	1.9	1.4
Reduced transcribing errors	2.1	1.6
Saved time	2.4	1.8
Helpful for data entry	2.5	1.8
Significant improvement	1.9	1.3
Less need for clarification	1.9	1.9
Contained less errors	N/A	1.3
Improved order timeliness	N/A	2.5

As part of the survey, prescribers were asked about the series of potential problems associated with an ordering tool. Prescribers were neutral toward the statements, that TPNCalculator carried the risk of inaccurate programming (3.3), had limited scope and was not designed to handle all clinical cases (3.0), had potentially incomplete information/missing data (3.0), redirected provider priorities (3.6), and generated false expectation such as being alerted to all problems (3.0). Prescribers disagreed that TPNCalculator caused data overload in the user (4.1). Using separate online questionnaires, we also surveyed 8 pediatric pharmacists (73% of pharmacists) and 43 neonatal nurses (42% of nurses). Comparing TPNCalculator and the paper form on a Likert scale from 1 (strongly agree) to 5 (strongly disagree), pharmacists and nurses agreed that TPNCalculator was easier to read, easier to learn, resulted in less need for order clarification. Pharmacists reported that TPNCalculator resulted in fewer errors, saved time and was helpful for data entry (Table 2).

Discussion:

Adverse drug events are common affecting as many as one in every 25 hospitalized patients.⁷ The ADE Prevention Study Group reported, that few risk factors are patient related suggesting that rather than targeting ADE-prone individuals, prevention strategies should focus on improving medication systems.⁸

After identifying a medication ordering process with significant risk for adverse drug events (ADE), we designed, implemented and evaluated a web-based medical information system (TPNCalculator) to improve the ordering process and reduce ADE. We used our working hypothesis, that underlying system failures/problems could be corrected with inexpensive, pragmatic problem solving approaches. A deliberate attempt was made to focus only on the "broken" link in the ordering process, "fix it" and preserve the rest of the process. Further, interface design was based on existing paper forms to provide users with maximum comfort level, minimize required training (usually less than 10 minutes) and permit existing order-processing flow to remain intact. Further, the use of participant/observers as programmers, designers and testers eliminated the need for extensive life cycle assessment. Using this approach, the complete design process (one Cold Fusion™ programmer) and quality assurance (one nutritionist and one pharmacist) took three weeks (approximately 200 man-hours), which starkly contrasts with other ongoing clinical medical informatics projects at Johns Hopkins Hospital. Modifications of TPNCalculator require minimal

intervention, since any change made on the server is immediately available to all users throughout the system.

Evaluation of error rates and user surveys revealed an overwhelming success. We reduced the total number of errors by over 60 percent. Calculation errors were eliminated through TPNCalculator and knowledge problems drastically reduced. Users of the system (including those only involved peripherally such as nurses) were enthusiastic and supportive and compared it favorably to the prior paper based system. We experienced significant pressure to make TPNCalculator available to all units in the children's hospital and to an affiliated hospital NICU once residents had used it during their NICU rotation. As a result, six months after the development of TPNCalculator, it was deployed throughout the JHH Children's Medical & Surgical Center. Even when prompted for potential problems with TPNCalculator during the survey, users did not estimate risks to be higher than in the paper system.

While TPNCalculator corrected a number of system problems, it contained however its own (although small and not significant for patient safety) system failure. We saw a drastic increase in the TPN orders without order ID (page number). Once this problem was identified, TPNCalculator was first modified to prompt the user for a page number and later an automatic page number creation rule was added. During a recent review there were no longer any orders without order page number.

Developing TPNCalculator would not have been possible without certain information infrastructure conditions already in place at JHH. We relied on the availability of public workstations in all clinical areas where providers might order TPN. If access to computers would have required traveling (even a short distance) or a waiting period, we suspect that users' enthusiasm for this application would have been drastically diminished. Further, the decision by JHH management to provide an Internet browser on all workstations was crucial to implementation. Allowing Internet browsing on public clinical workstations is not a universal practice as demonstrated by differences even among the hospitals within the Johns Hopkins Health System.

We have demonstrated that pragmatic approaches to adverse drug events involving simple medical information systems can be successful both in reducing the number of errors as well as increasing user satisfaction. The approach used in the development of TPNCalculator, which could be called "*Find it, fix it and forget it*", identifies a specific problem and uses existing infrastructure to develop a pragmatic medical informatics solution to the problem while leaving the remaining system

intact. By limiting the number of people involved in the process of problem identification, development, testing and deployment, the utilized resources such as time and manpower can be drastically reduced without losing effectiveness. While this approach carries a greater risk for software design flaws, in our opinion this risk can be minimized by using participant/observers in the development and is further offset by the significant gains through early implementation and cost reduction.

Conclusion:

Low-cost, pragmatic approaches utilizing Internet technology in the design of medical information systems might pose a viable alternative for the prevention of adverse drug events.

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