

Consensus Development Conference on the Safety of Intravenous Drug Delivery Systems

Consensus Statement

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Consensus Development Conference on the Safety of Intravenous Drug Delivery Systems

Consensus Statement

The purpose of this Conference was to evaluate the relative safety of currently available non-electronic intravenous drug delivery systems. An interdisciplinary expert panel reviewed six systems, and compared them based on safety, cost, simplicity of use, and amount of education and training required for safe and proper use. This evaluation focused on intravenous drug delivery systems in acute care hospital settings, and did not focus on specialized IV systems used in intensive care or pediatrics. Furthermore, electronic devices were excluded. The recommendations apply to hospitals of all sizes although certain systems may be most practical depending upon size, resources available, and levels of patient acuity.

The intent of this statement is to offer guidance to institutions to evaluate, appraise and select methods for administering intravenous drug therapy. These systems are part of the medication use process. As such they should ensure, to the extent possible, that the right drug be given in the right dose, by the right route by the right person to the right patient at the right time. Intravenous drug therapy should also be monitored for treatment outcomes including monitoring for adverse drug events and IV therapy complications. Before addressing the specific systems a number of caveats were considered by the panel. Any intravenous drug delivery system will only be as good as the safety management systems designed around it. In addition, such systems are necessarily multidisciplinary, and excellent interdisciplinary communication will be required for any to be successful. One way to improve system performance is to minimize the number of steps from preparation to administration, without compromising the steps that add safety. It is also safer to give medications orally when possible. Safe delivery of intravenous medication should include the following:

- Mechanisms, such as a double check by a pharmacist or bar code labeling, are built into the medication use system so that the wrong drug or dose is not dispensed or administered.
- Simplification and standardization should be employed to minimize variability of available IV systems and drug concentrations.
- Concentrated solutions should be removed from patient care areas.
- When on-site preparation of intravenous admixtures is needed, it should be prepared in the pharmacy whenever possible.
- The system used should maximize nurses' and pharmacists' time spent on improving patient care. None of these systems should replace careful monitoring of the patient before, during and after intravenous drug administration.
- Intravenous drug doses should be thoroughly and properly labeled including patient specific information.

Methodology

A chairperson was appointed and an interprofessional panel of independent experts was selected to plan the conference (appendix A). The NIH consensus development conference methodology was used¹. A detailed review of the literature was performed (appendix B).² Speakers were invited to present reviews of six intravenous drug delivery systems (appendices C, D and E). Six intravenous drug delivery systems were reviewed, including: IV push, volume control chambers, augmented IV push (e.g., syringe pumps), point-of-care activated systems, pharmacy-based intravenous admixture systems and manufacturer-prepared products. A six-person panel consisting of two physicians, two nurses and two pharmacists was asked to prepare a consensus statement on the safety of intravenous drug delivery systems (appendix F).

A decision analysis methodology was used to rank the systems based on four domains: safety, cost, simplicity of use and education/training³. Systems were numerically scored from one to three with one being a negative ranking and three being a positive ranking. The scores were then totaled to reach a final ranking. In the final rankings, safety and cost were given higher weights and factored to a 100-point scale (safety had a maximum of 36 points, with cost a maximum of 28; 18 was the maximum for the other categories).

Scores and Rankings

Table 1
Decision Analysis Scores

Rank	1	2	3	4	5	6
System	Manufacturer-Prepared	POC Activated	Pharmacy-based IV Admixture	IV Push	Augmented IV Push	Volume Control Chamber
a. Safety <i>(36 max)</i>	36	31	31	17	19	19
b. Cost <i>(28 max)</i>	22	24	21	21	12	10
c. Simpl. <i>(18 max)</i>	18	15	17	11	10	7
d. Train'g <i>(18 max)</i>	18	15	14	7	11	8
Total <i>100 max</i>	94	85	83	56	52	44

Definitions:

a. **Safety** is defined as adverse drug events (eg. medication errors and adverse drug

- reactions), risk (to both patient and employee), infection, phlebitis, etc.*
- b. **Cost** is viewed from the system perspective, and is defined as cost of acquisition, labor, education/training, as well as the cost of medication errors and ADE's.
 - c. **Simplicity of use** is defined to include number of steps and personnel involved in the process, time performing the tasks, and the learning curve.
 - d. **Training** is related to each discipline as necessary and appropriate.

Discussion

A detailed review of the literature summarizing the studies of each of these systems was published and provided to the panel before the Conference². The following conclusions were reached by the panel based on information presented by the speakers.

Manufacturer-prepared (e.g., premixed or frozen products)

Manufactured products were considered by the panel to be the safest system because of quality assurance built into the preparation process. The final formulations for these drug doses are iso-osmotic which may result in a lower incidence of phlebitis. The labeling of the product with the name and dose of the drug and diluent provides an additional safeguard. This system lends itself to more rapid availability of the dose and does not require that doses be calculated or manipulated further by the nurse. It may also free pharmacists and nurses to devote more time to other critical activities associated with the safety of intravenous drug delivery, such as IV to P.O. conversion programs. This system also lends itself for use in smaller hospitals without the human resources or facilities to make their own intravenous doses. This system may increase acquisition costs, but the overall system costs are balanced by reduced preparation costs and wastage rates. If products are placed directly in patient care areas however, the double checks by a pharmacist are more likely to be bypassed, increasing the potential for an error unless bedside barcoded products are used. Although not all

medications or doses are available with this system, a large proportion is available.

Point-of-care activated

These systems have some of the advantages of manufacturer-prepared products but require an additional step to mix the drug and diluent. This enables the rapid preparation of less stable drug products at the point of care, but introduces a potential for error if the drug is not activated or the mixing is incomplete. There is some evidence that in approximately one in two hundred doses, activation does not occur. Staff orientation, training, and quality assurance are needed with this system to ensure that complete mixing or activation occurs. These products are suitable for storage in automated dispensing machines. When products are placed in patient care areas for direct dispensing however, the double check by a pharmacist is more likely to be bypassed, increasing the potential for an error. Although not all doses are available with this system, a large proportion is available. There may be less wastage with this system compared to pharmacy-based intravenous admixtures.

Pharmacy-based intravenous admixture

This system allows for maximum flexibility because any dose can be prepared based on patient need. Almost all hospitals will use this system for preparation of some intravenous doses. Properly labeled products with patient-specific information are produced. A pharmacist double check is less likely to be bypassed resulting in an extra safety step that is built into this system. Fewer quality checks in product preparation occur with this system compared to manufacturer prepared products. In addition, there may be delays in getting the product to the patient care area in a timely manner. A full pharmacy-based intravenous admixture system may be more practical in large hospitals than small hospitals. Some data suggest that error rates are higher than with manufacturer-prepared or point-of-care activated systems⁴.

IV push

Doses that do not require calculation can be easily prepared and administered at the bedside. Premade syringes add an extra measure of safety. When the nurse prepares the dose, this system allows for the most timely administration of a dose, providing the nurse has time to prepare it. However, a system in which nurses prepare doses is often missing many of the quality checks and safeguards of the previous systems, thus calculation errors may occur. Pharmacist or manufacturer-prepared doses are preferable to nurse prepared doses. Regardless of who prepares the dose, the rate of infusion is less likely to be controlled. When errors occur, the adverse effect is more immediate, therefore there is little time to respond. Careful selection of those drugs that can be administered safely by IV push is essential. A list of medications that are approved for IV push administration should be developed and maintained. Extensive training and competency validation programs should be in place for nurses who give medications by direct IV push.

Augmented IV Push

Augmented IV push systems, like syringe pumps, have the advantage of better controlling the rate of infusion and rely on products prepared in the pharmacy, thus providing a double check and reduced chance of preparation error. They have the disadvantages of requiring a major capital equipment investment and increasing labor and storage cost compared to manufacturer-prepared and point-of-care systems. There should be added caution for site monitoring for infusion therapy complications. They also require more training to assure proper use. Careful inventory management for hardware is required to ensure that doses can be given at the right time.

Volume control chamber

Volume control chambers have the advantages of offering quick access for intravenous drug

delivery and enabling careful control of fluid volume. They have disadvantages in that they provide poor control over the rate of delivery and the opportunity for mixing of incompatible drugs. Drugs administered using this system are in an unlabeled container after the drug is placed in the chamber, increasing the risk of not knowing what is being infused. In addition, despite the similarity to and safety problems of the IV push system, training and competency validation for nurses who use this system are less common. This system also is more expensive than the IV push system, but may be less expensive than manufacturer prepared or point of care activated systems if therapy extends longer than a few days.

Conclusion and Panel Recommendations

Three systems scored higher and were viewed by the panel as being superior intravenous drug delivery systems. They are: manufacturer-prepared, point-of-care activated, and pharmacy-based intravenous admixture programs. Systems that were ranked lower were IV push, volume control chambers and augmented IV push. Most hospitals will have to use a blend of systems, because all products are not available or appropriate as manufacturer-prepared or point-of-care products. It is recognized that in certain circumstances one system may be preferable to another. For example, in the case of a medical emergency and for certain drug products, IV push may be the preferable system. The panel recommends when choices are available and for general use, the more highly ranked systems should be chosen to maximize safety and simplicity, and to minimize training. When IV push, volume control chambers and augmented IV push systems are used, increased vigilance may be required to assure safety. Greater costs and staff time may also be incurred. Given the data presented, the panel found none of the intravenous drug delivery systems inherently unacceptable. Individual products were not evaluated. Organizations may have incremental costs and safety issues when changing systems.

Bar coding of intravenous drug doses has the potential for improving patient safety but standardization of the format for bar codes is needed in order to move forward in this area.

Once bar codes are included on marketed IV therapy products or pharmacy labels, safe processes must be designed to accommodate this feature. The safety of point-of-care activated systems could be improved by providing feedback to confirm activation to the end user.

The panel concluded that further work is needed to clarify safety and cost issues associated with intravenous drug delivery systems. Little work has been published to evaluate the human factors engineering aspects of these systems including the impact of environmental factors. Because intravenous drug delivery systems are part of the hospital unit-dose system, the optimal system provides doses that do not need to be manipulated at the point of care. Information about medication errors, adverse drug events and IV site complications associated with these systems is also insufficient and warrants further study.

References

1. Guidelines for the planning and management of NIH Consensus Conferences Online. Bethesda (MD): National Institutes of Health, Office of the Director, Office of Medical Applications of Research; 1993 May. 13 p. Updated March 1995.
2. Schneider PJ. A review of the safety of intravenous drug delivery systems. Hospital Pharmacy. 1999;24:1044-56.
3. Witte KW, TA Eck and DP Vogel. Decision analysis applied to the purchase of frozen premixed intravenous antibiotics. American Journal of Hospital Pharmacy. 1985;42:835-9.
4. Flynn EA, RE Pearson, KN Barker. Observational study of accuracy in compounding i.v. admixtures at five hospitals. American Journal of Health-System Pharmacy. 1997;54:904-12.

Note: Citations for the references reviewed before the Conference are included as an annotated bibliography as Appendix B. Citations for the references used by speakers are included as Appendix E.

Appendix A

Program Planning Committee

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Appendix B

Annotated Bibliography

(in chronological order)

1. Patterson TR and KA Nordstrom. An analysis of intravenous additive procedures on nursing units. AJHP, 1968;25:134-37.

Increasing attention is being focused on intravenous additive procedures. The pharmacy and nursing services at the Louisville Veterans Administration Hospital conducted a survey for a period of one month to determine how many solutions were given, the number of solutions were given, the number of solutions containing additives, the amount of time needed to prepare solutions for administration, the time interval between preparation and administration, the number of different drugs and most frequent combinations added, and the areas where pharmacy could be of assistance. The study was self-reporting; nurses filled out data sheets and returned them to the pharmacy for daily tabulation.

The results are presented in table form. They show that 86 percent of the intravenous solutions administered contained at least one additive. The data are discussed and partial solutions to problems which appeared are considered.

Data collected in this study are compared to results of two other studies in which have been published. The study provided valuable information about preparation and administration of intravenous solutions in this hospital.

2. Miller WA, GL Smith and CJ Latiolais. A comparative evaluation of compounding costs and contamination rates of intravenous admixture systems. Drug Intell Clin Pharm, 1971;5:51-60.

The purpose of this study was to make a comparative evaluation of four intravenous admixture system including an open system, a closed system without an air vent, a closed system with an air

vent, and a plastic bag system. Specific objectives were to determine which system was the most economic in a parenteral admixture system, which assured minimal contamination and what was the most suitable technique for transferring drugs to IV solutions. Technicians were observed preparing IV admixtures to determine the relative costs of each system and end point sterility testing was used to determine safety. The results showed that the open system was the least expensive but the least safe. Contamination rates were not different between compounding environment (nursing unit vs laminar flow hood) suggesting that contamination resulted from poor aseptic technique rather than the lack of an aseptic environment.

3. Arnold TR and CD Hepler. Bacterial contamination of intravenous fluids in unsterile air. AJHP, 1971;28:614-9.

This paper reports an investigation of the relationship between microbial air contamination and parenteral solution contamination after opening the container in unsterile air and after the addition of drugs to the container.

Two situations were found in which the incidence of contamination was nearly 10% although the overall contamination encountered in this study was low. Given the correct set of circumstances there is a potential for infection even from low levels of contamination. Further research into control procedures that are applicable to any hospital is recommended.

4. Thur MP, WA Miller and CJ Latiolais. Medication errors in a nurse-controlled parenteral admixture program. AJHP. 1972;29:298-304.

The central purpose of this study was to determine by performance observation, whether nurses do or do not commit errors when they control the preparation and administration of parenteral admixtures.

One hundred observations (30.2% of all admixtures prepared in the study hospital during the observation period) were made on medical-surgical nursing units in a private community hospital. Results showed a 21% medication error rate when nurses prepared parenteral admixtures. The observed error rate was significantly higher than in other studies where nurses prepared and administered other types of medications even though in this study an error was defined only as preparation of wrong drug or iv solution, wrong dosage, unordered drugs or preparation of admixtures containing incompatible drugs. Deviations from recommended preparation procedures were also

noted but were not included in the overall 21% medication error rate calculations. Using the areas of recommended preparation procedures observed in the study, deviations were noted in 99% of the 100 parenteral admixtures prepared. Causes for the observed medication errors were also determined where practical Non-adherence to written nursing procedures, transcription errors involving medication cards, number of interruptions during each admixture and non-use of available information sources were the major factors leading to parenteral admixture medication errors. Conclusions of the study indicate that pharmacists are justified in preparing parenteral admixtures. Suggestions are made for future study of the significance of observed deviations in recommended preparation procedures.

5. Letcher KI, LD Thrupp, DJ Shapiro, et al. In use contamination of intravenous solutions in flexible plastic containers. AJHP, 1972;29:673-7.

*The rate of contamination of 1) intravenous solutions and admixtures prepared in flexible plastic containers by nurses and 2) the companion administration sets was evaluated following administration of the solutions to patients in a large municipal-community teaching hospital. Fluid from both intravenous solution containers and administration sets was sampled; bacteriological plating, inoculation and culturing techniques were utilized to detect microbiological contamination. Out of a total of 366 flexible plastic containers examined over a three-month period (the majority collected from surgical and intensive care units), 18 (4.9%) were found to be contaminated. A study of 365 administration sets showed a contamination rate of 5.5%. The majority of contaminants were observed as the growth of a single colony. This study indicates that flexible plastic intravenous solution containers have a low rate of contamination under actual use conditions when compared to previously reported studies of other intravenous fluid administration systems. The hazard of touch contamination continues to exist, as was shown by the predominance of *Staphylococcus epidermidis* in contaminated samples. Further examination is necessary, however, to determine the clinical significance of the observed contamination.*

6. Brodli P, C Kenny and AJJ Wood. Problems of administering drugs by continuous infusion. Br Med J,1974;1:383-5.

The incidence of incompatibilities in admixtures containing more than one drug was 15% when solutions were prepared by non-pharmacists in patient care areas.

7. Ravin R, J Bahr, F Luscomb, et al. Program for bacterial surveillance of intravenous admixtures. AJHP, 1974, 1974;31:340-7.

Protocols are suggested for 1) determining a hospital's probable contamination rate of large volume admixtures not containing anti-infective agents after they have been mostly administered, and 2) establishing a statistically valid sampling and sterility monitoring program involving five i.v. admixtures per day, five days per week, regardless of number of admixtures administered. When contamination rates exceed a calculated upper limit based upon a hospital's normal rate, the increase is probably due to an assignable cause, rather than the selection process, and should be investigated.

Reasons for implementing such a program, the possible value of air sampling studies and the authors' results utilizing the monitoring program are discussed. Also presented are recent recommendations of the Center for Disease Control regarding procedures to follow when septicemias related to i.v. therapy are suspected.

9. National Coordinating Committee on Large Volume Parenterals. Recommended methods for compounding intravenous admixtures in hospitals. AJHP, 1975;32:261-70.

Recommendations regarding 1) hospital receipt and storage of large-volume parenterals and 2) hospital compounding of intravenous admixtures are presented.

The recommendations are presented in a stepwise manner, and a self-evaluation form is included.

Also included is a pictorial illustration of a suggested dressing change for an i.v. catheter.

10. Sharf BA, JS Cockburn, DT Hans, et al. IV system contaminants and how they found them. Am J IV Ther. 1977;4:15-7.

11. Sanders LH, SA Mabadeje, KE Avis, et al. Evaluation of compounding accuracy and aseptic technique for intravenous admixtures. AJHP, 1978;35:531-6.

Intravenous admixtures containing potassium collected from three hospital pharmacies were analyzed for compounding accuracy, sterility and pyrogenicity.

The study was performed in two stages. During stage I, pharmacists and technicians were not informed of the study, but during stage II they were informed. In each stage 10 samples were collected from each person in the two personnel groups, analyzed and the results compared between the two personnel groups and the two stages.

Results of the study showed that without monitoring (stage I) pharmacists had a higher mean percent error and contamination level than technicians. With monitoring, however, pharmacists showed a lower mean percent error and contamination level than technicians. Both personnel groups showed a decline in their mean percent error in the second stage, but there were still 83 (39.5%) errors in compounding accuracy $\geq 6\%$. No positive results with the Limulus test for pyrogens were obtained.

It is recommended that a planned program of quality control be instituted for the preparation of i.v. admixtures by both pharmacists and technicians.

12. Perlstein PH, C Callison, M White, et al. Errors in drug computations during newborn intensive care. Am J Dis Child, 1979;133:376-9.

Medical personnel in a pediatric center were tested for their ability to correctly compute drug doses for sick newborns. One of every 12 doses computed by 95 registered nurses contained an error that would result in the administration of an amount that was ten times higher or lower than the dose ordered. The error rate was no different for experienced or inexperienced nurses. The test also included an evaluation of the nurse's ability to judge the appropriateness of the drug dose ordered for a specified infant. Experienced nurses tended to be more certain, although wrong in their judgment when compared to inexperienced nurses. Eleven pediatricians, when given the same test, scored higher than the nurses but still made errors at the rate of one of every 26 computations attempted. Five registered pharmacists who were tested demonstrated far better computational skills than either the nursing or physician group.

13. Allinson RR, PE Stach, TS Sherrin, et al. Compounding times and contamination rates for preparing IV admixtures in three types of plastic containers. AJHP, 1979;36:513-7.

The compounding times and contamination rates associated with the preparation of admixtures in three different plastic i.v. containers of dextrose 5% in water were compared.

The time required for a technician to prepare, in a laminar air flow hood by the needle and syringe technique, 120 admixtures in each of three different plastic i.v. Containers was measured and recorded by two investigators. The 360 admixtures were tested within one hour of preparation for sterility using an enriched brain heart infusion broth.

The total time required to compound the i.v. admixture varied significantly with container design ($p < 0.01$), preparation being fastest with the Accumed container, followed by the LifeCare then the Viaflex containers. The major contributing factors to increased compounding time were 1) removal of outer wrap, 2) swabbing of LifeCare and Viaflex medication ports with isopropyl alcohol pads and 3) freeing of the hangar flap from the Viaflex container. Sterility tests revealed no detectable contamination of any of the admixtures.

Container design of plastic i.v. containers did influence the preparation time for admixtures but did not influence admixture sterility.

14. Stolar MH. Assuring the quality of intravenous admixture programs. AJHP, 1979;36:605-8.

Several aspects of quality assurance (QA) methods in i.v. admixture programs are discussed, and basic framework for developing QA programs for admixture services is presented.

The objective of QA is to insure that admixture products: 1) are therapeutically and pharmaceutically appropriate to the patient; 2) are free from microbial and pyrogenic contaminants; 3) are free from undesirable levels of particulate or toxic contaminants; 4) contain drugs in correct amounts; and 5) are labeled, stored and distributed under principles of good drug control.

Three types of QA criteria bases which may be used as indicators of quality are discussed (resources, facilities and organization; required procedures; end-products or results). Because end-product monitoring has certain limitations in the admixture setting, QA must rely heavily on procedure-centered review methods. General guidelines for developing QA programs are outlined. Adherence to procedure is the key to assuring the quality of admixture products. In developing a QA program, the highest priority should be given to the education and training of admixture personnel, particularly with respect to aseptic technique and pharmaceutical calculations.

15. Paxinos J, RJ Hammel and WL Fritz. Contamination rates and costs associated with the use of four intermittent intravenous infusion systems. AJHP, 1979;36:1497-1503.

Rates of contamination, costs and efficiency of four intermittent intravenous infusion systems (System1--inline burette; System2--piggyback with minibag; System 3--tandem piggyback with inline burette; and System4--piggyback with manufacturer's drug container) were studied.

Solutions for each of the four i.v. Infusions sets were prepared by pharmacy technicians or nurses. Nurses hooked up and adjusted flow rates on each of the sets 27 times. Personnel times for initial assembly, dose preparation and flow-rate adjustment were measured by time and motion studies. Contamination rates were determined by culturing the filter unit of each set after four doses of the drug had been infused intermittently through it.

Mean total personnel times were lowest for System 4, followed in order by Systems 1, 2 and 3. System 1 had the lowest material costs followed in order by Systems 4, 3, and 2. Labor costs accounted for only a small portion of the total costs of each system and did not influence the rank order established by material costs. Only one incident of contamination resulted; this was with System 1. Although System 1 had the lowest total costs, these were only slightly lower than those of System 4 which was mechanically superior. Thus, System 4 is preferred. System 3 is a suitable alternative to System 4 when the dose of drug required is not available in a manufacturer's container.

16. National Coordinating Committee on Large Volume Parenterals. Recommended standards of practice, policies, and practices for intravenous therapy. AJHP, 1980;37:660-63.

Standards of practice, policies, and procedures for i.v. therapy are recommended for the improvement of patient care, to lessen mortality and morbidity, and to provide guidelines for quality assurance.

The recommended standards are based on the principle that intravenous therapy shall be developed and implemented in a manner that will provide and maintain the extraordinary level of care required for such therapy. The recommendations are grouped into the following categories: 1) education of i.v. therapy personnel, 2) policies to guide individuals who administer i.v. therapy, 3) problem areas in practices and procedures for i.v. therapy, and 4) equipment and supplies.

17. National Coordinating Committee on Large Volume Parenterals. Recommendations to pharmacists for solving problems with large volume parenterals - 1979. AJHP,

1980;37:633-7.

Recommendations to pharmacists for solving problems with large volume parenterals are made in the following areas: quality control for pharmacy based IV admixture programs, methods for storage and delivery of IV admixtures, use of in line filters, training for personnel preparing and administering sterile medications, IV therapy teams, and curricular issues in professional schools.

18. National Coordinating Committee on Large Volume Parenterals. Recommended guidelines for quality assurance in hospital centralized intravenous admixture services. AJHP, 1980;37:645-55.

Guidelines and methods for quality assurance for hospital centralized i.v. admixture services are presented.

Objectives to be used to assure quality of an i.v. admixture program are recommended and discussion of the guidelines is divided into 1) selection, education, and training of personnel; 2) in-process controls; 3) end-product testing; and 4) sampling guidelines.

Cumulative sum procedures are recommended for sampling products prepared in an admixture service.

19. Thompson WL and TD Feer. Incomplete mixing of drugs in intravenous solutions. Crit Care Med. 1980;8:603-7.

The uniformity of drug concentrations in IV admixtures prepared by nurses and pharmacists was discussed. Significant differences were found in the concentrations of admixed drugs delivered over time due to incomplete mixing. Less differences in uniformity was seen in admixtures prepared by pharmacists than in those prepared by nurses.

20. Schneider PJ. Review of the justification for parenteral admixture preparation. Hosp Pharm, 1981;16:476-84.

Pharmacy-based intravenous admixture programs are still not present in many hospitals today,

despite the length of time these programs have been advocated. This paper reviews the scientific, legal, and administrative basis for pharmacy-based centralized intravenous admixture programs. Key elements in developing admixture programs based on these points are reviewed.

21. Brier KL, CJ Latiolais, PJ Schneider, et al. Effect of laminar flow and clean room dress on contamination rates of intravenous admixtures. AJHP, 1981;38:1144-7.

The effect of laminar air flow conditions and clean-room dress on the microbial contamination rates of intravenous admixtures was investigated.

Intravenous admixtures were prepared by one investigator using aseptic technique under four environmental conditions: laminar air flow conditions with clean-room dress; laminar air flow without clean-room dress; clean table top with clean-room dress; and clean table top without clean-room dress. In each environmental condition, 350 admixtures were compounded. Negative-control samples (n=150) were also tested, as were 10 positive-control samples. Samples were tested in each of two growth media and incubated at 35EC for 14 days or until growth occurred.

The incidence of contamination of admixtures compounded in laminar air flow conditions was significantly less than the contamination of those compounded on a clean table top ($p < 0.05$) regardless of the operator's dress. The incidence of contamination of admixtures compounded while wearing clean-room dress was not significantly different from those prepared while not wearing clean-room dress regardless of the environment in which the admixture was prepared. The overall low level of contamination [0.79% {11/100}] was inconclusive regarding the effect of dress on the incidence of contamination when admixtures were prepared under LAF conditions.

It is concluded that, when one adheres to aseptic technique, the environment in which admixtures are compounded is the most important variable affecting the microbial contamination rate.

22. Leff RD and RJ Roberts. Methods for intravenous drug administration in the pediatric patient. J Ped, 1981;98:631-35.

Variation in the rate of iv drug delivery to the patient occurs secondary to influences of the site selected for injection of the drug into the iv system, the rate of flow of the iv solution, and the drug dosage volume. The involvement of each of these factors in producing varying rates of iv drug infusion is virtually assured by the wide range of drug dosage volumes and iv fluid rates required

within the pediatric population. Because of the importance of delivering medications at a known rate, a uniform protocol for iv drug therapy was developed for pediatric patients and implemented at the University of Iowa Hospitals and Clinics. The protocol, which utilizes either a syringe infusion pump or manual retrograde injection technique, has been shown to be a practical safe, dependable, and effective means to deliver both iv fluids and medications at a desired or known rate.

23. Rajchgot P, IC Radde and SM MacLeod. Influence of specific gravity on intravenous drug delivery. J Ped, 1981;99:658-61.

These investigators studied the infusion characteristics of two drugs, gentamicin and cloxacillin using a standard infusion system that included a volume control chamber, a pump, two Y sites and a final filter. They found that the specific gravity of a drug has a profound influence on its delivery at slow infusion rates and that inadequate mixing within a volume control chamber is responsible for this. Any reservoir included in an infusion system should be designed to ensure predictable mixing of drug and infusion medium.

24. Loeb AJ, DA Fishman and TR Kocilis. Premixed intravenous admixtures: a critical challenge for hospital pharmacy. AJHP, 1983;40:1041-43.

The advantages and disadvantages of premixed intravenous admixtures are discussed in the context of their effects on hospital pharmacy practice

Premixed i.v. admixtures offer the advantages of preparation-time savings, assurance of properly reconstituted drugs, lengthy expiration dating, and appropriate labeling. However, because not all drugs will be available from all three i.v. solution manufacturers, hospitals may be forced to use several types of i.v. containers and administration sets. Storage-space requirements will be increased, as the pharmacy will need to stock both premixed and unmixed products. Health-care personnel may be confused about whom to call (the drug manufacturer or the i.v. manufacturer) for drug information on premixed admixtures. Quantity discounts will likely decrease as fewer base i.v. solutions and unmixed drug products are purchased.

Plans should be made now to shift personnel from admixture preparation to clinically oriented programs and to develop new workload indicators for pharmacy departments.

25. Lee HE. Premixed intravenous admixtures: A positive development for hospital

pharmacy. AJHP, 1983;40:1043-4.

The development of premixed intravenous admixtures is reviewed in a historical context, and its effects on hospital pharmacy practice are discussed.

As pharmaceutical manufacturers introduce more i.v. medications in ready-to-use containers, the same complaints that were voiced by pharmacists about unit dose packaging and ready-to-dispense tablets and capsules are being aired. But premixed i.v. admixtures are a logical extension of the basic unit dose principle of providing a readily identifiable and ready-to-administer dose. The time and cost savings these products offer are needed in hospital pharmacies. Some of the disadvantages of these products--including storage and freezer space and multiplicity of administration systems--are overcome by proper planning and education of personnel. If fewer personnel are now needed to prepare i.v. admixtures, then those personnel should be used to improve patient care in other ways.

The use of premixed i.v. admixtures is a positive technological advance in drug packaging. Its advantages outweigh its disadvantages, and it will soon become the universally accepted form of i.v. drug packaging.

26. Nahata MC, DA Powell, DE Durrell, et al. Effect of infusion method on tobramycin concentrations in newborn infants. J Ped, 1984;104:136-38.

The purpose of this study was to determine the influence of three infusion systems, IVAC Model 530, IMED Model 965 and AutoSyringe, on the serum concentrations of tobramycin in newborn infants the first postnatal week. Tobramycin 2.5 mg/kg q 12 h was administered by one of these methods. The average interval to achieve peak concentrations was 5.5 times longer with the IVAC Y-site, three times longer with the IVAC flashball and 2.2 times longer with the IMED Y-site compared with AutoSyringe.

27. Salberg DJ RW Newton and DT Leduc. Cost of wastage in a hospital intravenous program. Hosp Forumul. 1984;19:375-8.

Reported a loss from IV product waste in one hospital of \$28,000 per year.

28. Wellman, GS, KM Hale, PJ Schneider, et al. Comprehensive intravenous admixture services: logistics and quality assurance in a university affiliated teaching institution. Hospital Pharmacy, 1984;19:601-6.

The role of supportive personnel, as well as the supervision of intravenous (IV) admixture compounding by staff pharmacists, should be clearly identified by the departmental manager. In doing so, the department should strive to achieve an optimal mix of professional and technical personnel with automated technology. Close attention must be paid to quality assurance in order to maintain the highest quality parenteral admixture. The logistics of comprehensive IV admixture services are described for a university affiliated teaching institution. Emphasis is made on a three-faceted approach to quality assurance, including technician training, end-product testing, and equipment maintenance.

29. Witte KW, TA Eck and DP Vogel. Decision analysis applied to the purchase of frozen premixed intravenous admixtures. AJHP, 42;1985:835-9.

A structured decision-analysis model was used to evaluate frozen premixed cefazolin admixtures. Decision analysis is a process of stating the desired outcome, establishing and weighting evaluation criteria, identifying options for reaching the outcome, evaluating and numerically ranking each option for each criterion, multiplying the ranking by weight for each criterion, and calculating total points for each option. It was used to compare objectively frozen premixed cefazolin admixtures with batch reconstitution from vials and reconstitution of lyophilized, ready-to-mix containers. In this institution the model numerically demonstrated a distinct preference for the premixed frozen admixture over these other alternatives. A comparison of these results with the total cost impact of each option resulted in a decision to purchase the frozen premixed solution that contributed most to this decision were decreased waste and personnel time. The latter was especially important since it allowed for the reallocation of personnel resources to other potentially cost-reducing clinical functions. Decision analysis proved to be an effective tool for formalizing the process of selecting among various alternatives to reach a desired outcome in this hospital pharmacy.

30. Leff RD, GF Johnson, A Erenberg, et al. Evaluation of an extension set for intermittent intravenous drug delivery to infants. AJHP, 1985;42:1358-62.

An intravenous administration set designed for delivery of drug doses to pediatric patients was tested in vitro for the effect of fluid density and flow rate on drug delivery, and delivery of drug by this extension set was compared in vivo with delivery by other methods.

Gentamicin (as the sulfate salt) and penicillin G potassium were used to represent low-density and high-density drugs, respectively; a 1-mL solution of each drug, labeled with carbon 14, was tested with each of two primary infusion solutions: 0.45% sodium chloride injection and 10% dextrose injection. The drug dose was injected via a port into a piston-containing chamber from which an equivalent amount of the primary fluid was displaced. Serial samples collected from the end of the filter-containing extension set were analyzed for drug concentration using, a liquid scintillation technique. In 12 infants receiving i.v. gentamicin, this delivery method was compared in a randomized crossover trial with delivery by a syringe pump and by i.v. push. Each delivery system was used on one of three consecutive days and serum gentamicin concentrations were measured by enzyme-multiplied immunoassay.

The time required for in vitro delivery of the dose was dependent on flow rate. Density of the drug solution or the primary i.v. fluid did not significantly affect drug delivery. Serum gentamicin concentrations were not significantly different for the three delivery methods, but variability of drug delivery was greatest with the pediatric extension set.

This pediatric extension set provides accurate and reliable drug delivery at primary infusion flow rates slower than 10 mL/hr when the drug dosage volume is 2-3 mL or less.

31. Rapp RP. Hospital intravenous drug administration in the era of prospective payment. Drug Intell Clin Pharm, 1985;19:146-9.

This editorial reviews existing methods to administer intermittent IV therapy based on costs to the institution. Systems reviewed include "auxiliary medication set" (volume control chamber), minibags, manufacturer's piggyback containers (empty), and "new systems" (spring driven syringe, battery powered pump, and vented, gravity-based syringe. It is noted that the volume control chamber increases the risk of contamination, and drug identity is lost after the dose is introduced into the chamber. Incompatibilities between drugs can be a problem as well. Minibag systems solve most of these problems, but are more expensive and can create problems with fluid overload and lack flexibility with selecting diluents besides dextrose 5% and saline 0.9%. The author recommends the empty manufacturer's piggyback systems because of cost and flexibility issues and thinks that syringe based systems have potential cost advantages also.

32. Smith TF and JG Kitrenos. Comparisons of seven methods of preparing and administering cefazolin sodium in small-volume injections. AJHP, 1986;43:1930-35.

The time and costs of preparing and administering cefazolin sodium small-volume injection using automated and manual systems were compared.

Doses of cefazolin sodium 1 g were prepared in batches of 100 using each of seven methods, and preparation and administration times were recorded during five time trials . Personnel time and total material costs were determined. Bulk-vial reconstitution methods included manual piggyback, manual 24-hour piggyback, and manual syringe systems and one automated syringe infusion method (Bard programmable dispensing pump). Three prefilled container systems (Faspak flexible plastic bags, manufacturers' partial-fill glass bottles, and cefazolin sodium 1-g vials reconstituted using the ADS 100 Physio-Control peristaltic pump and administered via the IVAC CRIS system) were compared with each other and with the bulk reconstitution methods.

Of the bulk-vial methods, total preparation process times were significantly shorter for the 24-hour piggyback system. Of the prefilled container systems, total preparation process time was significantly shorter for the Faspak system. Total daily administration process time was shortest for the IVAC CRIS system. Material costs per dose were lowest for the IVAC CRIS system and highest for the syringe pump systems (manual syringe and Bard syringe).

Although lowest cost per dose was identified with the IVAC CRIS system, the 240hour piggy back system was the system of choice on the basis of similar cost savings, its ability to manage primary fluids, and practicality of use at this institution.

33. Vogel DP, TA Eck and KW Witte. Calculation of product waste in IV Admixture program. AJHP, 1986;43:952-3.

This publication reviews the calculation method used to determine the added cost to a centralized IV admixture program that results from discarding unused products. Their formula for estimating waste is based on extrapolations from a study period where acquisition costs of supplies are tabulated and the number of reused IV admixtures are subtracted. Wastage rates of between 2.2 and 15.6 % were estimated in participating hospitals. With annualized costs ranging from \$3,341 to \$145,928 for these wasted solutions.

34. Akers MJ. Considerations in using the IV route for drug delivery. AJHP,

1987;44:2528-30.

This is an introductory article to a "Primer" series of articles (#'s 35-39 below) collectively titled "Current problems and innovations in intravenous drug delivery." It reviews the indications for the selection of an intravenous route for administering drugs, the complications of IV drug delivery (sepsis, thrombosis, phlebitis, air emboli, hypersensitivity, drug or fluid over dosage, particulate matter, drug incompatibilities and infiltration/extravasation). The author concludes that IV drug administration has many advantages, but requires consideration of the potential problems and hazards to ensure optimal drug therapy.

35. Rapp RP. Considering product features and costs in selecting a system for intermittent i.v. drug delivery. AJHP, 1987;44:2533-8.

This is a further elaboration by the same author on the same subject as reference # 31, but has more details about battery and spring operated syringe pumps as well as newer technologies such as the "controlled-release infusion system (CRIS), the ADD-Vantage system, as well as frozen and premixed minibag systems. Advantages and disadvantages of each of eight systems are summarized in separate tables in the text. The author does not recommend any single system but concludes that each hospital must decide what systems for intermittent IV drug delivery are best in its own situation. Internally performed time-motion studies of studies derived from the hospital pharmacy literature are recommended. It is stated that the system that is best overall for patients, nurses and pharmacists will be determined by future studies and requirements.

36. Nahata MC. Effect of i.v. drug delivery systems on pharmacokinetic monitoring. AJHP, 1987;44:2538-42.

This review presents the factors that can affect the accuracy of intravenous drug delivery. These include flow rate, site of drug injection into the IV set, specific gravity of the drug solution, the size and volume of the IV tubing and the type of infusion device. In adult patients, a study was reviewed where variability in flow rates was documented. Differences were attributed to the ability of personnel to properly set and monitor flow rates, differences in the features of intravenous sets, and patient venous pressure. The advantages of volumetric chambers are listed and include: accuracy in determining fluid volume delivered and cost. It is concluded that a recommendation of one ideal

infusion system for all institutions is not possible, but that awareness of the problems of IV drug delivery is critical.

36. Zenk KE. Intravenous drug delivery in infants with limited i.v. access and fluid restriction. AJHP, 1987;44:2542-5.

This article addresses the specific needs of infants with limited IV access and fluid restriction. The following techniques are discussed: concentrating medications and nutrients, "co-infusion" (adding drugs together), retrograde administration, IV push, use of other routes of administration and discontinuing the medication.

37. Reilly KM. Problems in administration techniques and dose measurement that influence accuracy of i.v. drug delivery. AJHP, 1987;44:2545-50.

This article reviews the problems associated with accurate delivery of drugs by the intravenous route to pediatric patients. Some factors that affect accuracy include overfill in IV solutions and fluid in IV tubing, drug half-life, infusion technique (eg. choice of proper sets), changes in equipment. Techniques to avoid these problems are reviewed and include giving drugs by IV push, retrograde infusion, volumetric chamber sets, and syringe pumps. In addition to the choice of drug delivery method, the importance of staff education is stressed.

38. Colangelo A. Drug preparation techniques for i.v. drug delivery systems. AJHP, 1987;44:2550-3.

This article reviews the techniques for preparing IV drug doses for IV piggyback systems, syringe pumps, "drug manufacturers' piggyback" systems, frozen premixed solutions and "wet-dry" systems (ADD-Vantage). The author points out that the first three of these systems require the most work in the pharmacy department. He suggests that the increased cost of premade products simply shift costs from personnel to product, and reduce the amount of flexibility in preparing non-standard doses.

39. Piccoro JJ Jr. Development of an institutional i.v. drug delivery policy. AJHP, 1987;44:2577-9.

This article summarizes the types of drug delivery policies that are needed to assure safe IV drug administration. Examples include IV drug administration guidelines (eg. use of metered chambers vs minibags), IV push drug administration policies (which drugs, where they can be given, who can give them, training requirements), intravenous infusion device policy (what drugs, where, type of devices), IV set change policy (how often), and IV solution filtration policy.

40. Kirschenbaum BE, L Cacaee, RJ Anderson, et al. Personnel time and preparation costs for compounded versus premixed intravenous admixtures in three community hospitals. AJHP, 1988;45:605-8.

Personnel time requirements and costs associated with the ordering preparation, and administration of manually compounded versus premixed i.v. admixture were determined at three for-profit community hospitals.

The three hospitals, all owned by one corporation, ranged in size from 160 to 239 beds. At each hospital, pharmacists or technicians manually compounded admixtures in glass bottles or plastic bags. Work flow descriptions of the activities involved in the preparation and administration of admixtures were created, and time-motion and work-sampling techniques were used to observe three to five pharmacists or technicians in each hospital over a seven-day period. Drug waste also was monitored. At the conclusion of the baseline study, each hospital switched to the premixed products that they had chosen to evaluate; admixtures of cefazolin sodium, cefoxitin sodium, gentamicin sulfate, and potassium chloride were available. After a two-week acclimation period, the seven-day study was repeated.

Average total labor time ranged from 5.6 to 9.1 minutes per compounded admixture to 4.1 to 7.7 minutes per premixed admixture. The percentage of total labor time devoted to compounding, delivering, stocking, and other physical handling of materials decreased by 64% for admixtures of gentamicin or potassium chloride and by 67% for admixtures of cefazolin or cefoxitin. The average reduction in annual costs for accessories, labor time, wasted drugs, and inventory at each hospital was \$15,000. Additional savings were realized from overall lower acquisition costs for the premixed products at the study hospitals.

The use of premixed i.v. admixtures reduced preparation time and labor and material costs in three small- and medium-sized community hospitals.

41. Foltyn Smith C and RJ Amen. Comparison of seven methods of preparing and

administering small-volume injections. AJHP, 1988;45:1896-1901.

The time and costs associated with preparing and administering small-volume injections using seven infusion systems were compared.

Thirteen demographically diverse hospitals were chosen at study sites, all under a common protocol. The systems compared were the CRIS controlled-release infusion, minibag, frozen ready-to-use minibag, drug, manufacturer-supplied piggyback, syringe pump, volume-control set, and ADD-Vantage systems. Care was taken to ensure that similar drugs (i.e., drugs with equivalent preparation steps) were studied in the same test systems at the hospitals.

The mean preparation time for the CRIS controlled-release infusion system was significantly longer than the times for the frozen ready-to-use minibags and ADD Vantage system and significantly shorter than the times for the minibag and syringe pump systems. Medication administration time for initial doses was found to be significantly shorter with the CRIS system than with the volume-control and ADD-Vantage systems; the time required to administer subsequent doses of small-volume injections was shorter with CRIS than with all other systems except the ADD-Vantage system. When total material costs plus the cost of labor involved in both pharmacy and nursing were combined, CRIS proved to be the least expensive system to use, primarily because of the time and cost savings associated with its use for administration of subsequent doses.

Of the seven admixture systems studied, the CRIS system proved to be the least expensive to use when labor and material costs associated with preparation and administration of six doses of an injectable drug were considered.

42. Dasta JF, MF Bonfiglio, NG Rague, et al. Accuracy and variability of intravenous theophylline preparations. Ther Drug Monit. 1990;12:554-7.

Numerous physiologic factors affect the disposition of theophylline. One non-patient factor that can influence steady-state theophylline concentration is the administered dosage. The accuracy and variability of hospital pharmacy-prepared i.v. admixtures of theophylline has not been quantitated. A study was designed to evaluate variation in theophylline concentrations from two sources of theophylline admixtures--one by a hospital pharmacy i.v. room and one by a pharmaceutical manufacturer making a pre-made product. For the theoretical 1.6mg/mL admixture, the mean theophylline concentration of the pharmacy-prepared solution was lower than that of premixed, whereas the absolute percent error of the premixed product was less than that of the pharmacy bags. For the theoretical 2.3 mg/mL admixture, the theophylline concentration of the premixed

product was lower than that of both pharmacy products, whereas the absolute percent error of the pharmacy bags was less than that of the pharmacy bottles and premixed bags. Our data imply that variability in theophylline concentration can occur depending on the method of preparation, drug concentration and formulation. Pharmacokinetic monitoring of the theophylline should include an assessment of methods of i.v. drug preparation. Pharmacy departments should have a policy that assures consistency in the method of preparation of i.v. drugs.

43. Vaida AJ and C Gabos. Intravenous admixture systems. In: *Handbook of Institutional Pharmacy Practice*, 3rd ed. ASHP; Bethesda MD, 1992, pp 175-92.

This is a textbook chapter that reviews the rationale and components of a pharmacy-based intravenous admixture program and aspects of small volume infusions, enlarge volume infusions and special admixtures, such as nutrition and chemotherapy.

44. ASHP technical assistance bulletin on quality assurance for pharmacy-prepared sterile products. AJHP, 1993;50:2386-98.

This is a statement of the American Society of Health-system Pharmacists that summarizes the recommendations for pharmacists to establish quality assurance procedures for preparation of sterile products, including drugs that are administered by the intravenous route. It categorizes products according to risk level based on the complexity of preparation and the storage conditions that exist after the product is prepared. Procedures are recommended in the following areas: policies and procedures, personnel education, training and evaluation, storage and handling, facilities and equipment, garb, aseptic technique and product preparation, process validation, expiration dating, labeling, end product evaluation and documentation.

45. MCB O'Hare, AM Bradley, T Gallagher, et al. Errors in administration of intravenous drugs. BMJ, 1995;310:1536-7.

46. Hunt ML and RP Rapp. Intravenous medication errors. J Intrav Nurs, 1996;19(3 suppl):S9-15.

In a clinical study, it was reported that based on the number of adult patients admitted to two hospitals, medication errors amounted to almost 4,000, an alarming figure considering that many were thought to be preventable. Today's health care environment dictates the type of care patients receive and from whom, and the potential for medication errors. This article discusses the factors concerning the prescribing of IV medications, preparing the medications, and administering them competently by nurses and pharmacists.

47. Flynn EA, RE Pearson and KN Barker. Observational study of accuracy in compounding i.v. admixtures at five hospitals. AJHP, 1997;54:904-12.

Rates of errors in i.v. admixture compounding at five U.S. hospital pharmacies were studied. Pharmacy staff members at five hospitals representing each U.S. geographic region were observed as they compounded sterile products in order to record the medication, dose, base solution, and other details. Intravenous admixtures, antineoplastic preparations, parenteral nutrient solutions, and ready-to-use products were included. Observations took place for five days at each pharmacy. The observers' notes were checked against the labels used to prepare the doses; any deviation was considered an error. The clinical importance of each error was assessed for its potential to affect a patient adversely.

The mean error rate for the five hospitals combined was 9% (145 errors for 1679 doses), excluding ready-to-use products. Mean error rates for individual pharmacies ranged from 6% to 10%. Wrong-dose errors were the most common type of error. Parenteral nutrient solutions had the highest error rates--37% for manual preparation and 22% for preparation that was partly automated. Of every 100 errors, 2 were judged to be potentially clinically important.

In five U.S. hospital pharmacies, the observed error rate for compounding i.v. admixtures was 9%.

48. Lesar TS. Errors in the use of medication dosage equations. Arch Ped Adolesc Med, 1998;152:340-4.

Calculation errors in prescribing are a well recognized problem; however, no systematic studies of actual errors involving calculations or other errors in the use of drug dosage equations are available. The objective of this study was to characterized the nature and potential adverse consequences of actual prescribing errors involving dosage equations. Two hundred consecutive prescribing errors

with potentially adverse outcomes involving dosage equations were analyzed. Errors most commonly involved children (69.5%) and antibiotics (53.5%). Forty-two percent of errors were considered to put the patient at risk for a serious or severe preventable adverse outcome. Errors in decimal point placement, mathematical calculation, or expression of dosage regimen accounted for 59.5% of dosage errors. The dosage equation was wrong in 29.5% of dosage errors. The use of equations to determine medication dosages presents considerable risk to patients for errant dosing and subsequent adverse events or therapeutic failure. Errors may occur in any component of a dosage equation. Health care organizations should implement procedures to reduce the risk for errors resulting from the use of dosage equations.

Appendix C

Program Schedule

September 26, 1999

18:00- 20:00 Dinner with Panel members and Planning Group

September 27, 1999

8:30-11:00 Review of conference plans and Panel briefing

11:00-12:00 Brunch for registrants, Faculty and Panel

12:00-12:30 Conference overview by Panel Chair

12:30-16:10 Plenary sessions and discussion

12:30-12:50 IV Push system - Roxanne Perucca, RN, MSN, CRNI

12:50-13:10 Discussion

13:10-13:30 Augmented system - Donald Bennett, R.Ph.,MBA
13:30-13:50 Discussion
13:50-14:10 Point of Care system - Doug DeJong, R.Ph., MBA
14:10-14:30 Discussion
14:30-14:50 Pharmacy-based IV Admixture - Paul W. Abramowitz,
Pharm D
14:50-15:10 Discussion
15:10-15:30 Break -
15:30-15:50 Manufacturer Prepared system - Kenneth W. Witte,
Pharm D
15:50-16:10 Discussion

16:10-17:10 Public statements from organizations
17:10-18:00 General questions and comments
18:00-21:00 Panel dinner and drafting of statement
and
buffet dinner for registrants

September 28, 1999

07:30-08:30 Continental Breakfast
08:30-09:00 Presentation of draft statement by Panel Chair
09:00-10:30 Discussion
10:30-11:30 Revision of statement by Panel
11:30-12:00 Presentation of final statement by Panel Chair
12:00 noon Program adjourns

Appendix D

Program Faculty

Roxanne Perucca, RN, MSN, CRNI	IV Push/Volume Control Chambers	University of Kansas Medical Center, Kansas City, KS
Donald L. Bennett, R.Ph., MBA	Augmented IV push	Mt. Carmel Medical Center, Columbus, OH
Doug DeJong, R.Ph., MBA	Point of care activated	St. Lukes Shawnee Mission, Kansas City, MO
Paul W. Abramowitz, Pharm.D.	Pharmacy-based intravenous admixture	Department of Pharmaceutical Services, University of Iowa Hospitals and Clinics Iowa City, IA
Kenneth W. Witte, Pharm.D.	Manufacturer prepared	University of Illinois at Chicago, College of Pharmacy, Chicago, IL

Appendix E

Speaker's References

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B. Augmented IV Push, Donald L. Bennett, R.Ph., MBA

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C, MANUFACTURER PREPARED, Kenneth W. Witte, Pharm.D.

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Appendix F

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