Quality assurance for hemodialyzer reprocessing: minimizing risks

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Reprocessing of hemodialyzers is a well-established practice in the United States. In 1999, 80% of the dialysis centers had dialyzer reprocessing programs.[1] Many researchers, including this author, have studied various aspects of performance and quality control for reprocessed hemodialyzers. Much of the literature associated with these studies confirms dialyzer reprocessing can be a safe and effective practice when appropriate quality control measures are in place.[2,3,4]

However, dialyzer reprocessing will not be safe, just as a dialysis treatment will not be safe, if performed improperly. Two recent large studies indicate a potential conditional increase in relative risk for patient mortality when a particular germicide is used as the dialyzer reprocessing agent[5,6] Results from studies such as these underscore the importance of implementing an effective dialyzer reprocessing quality assurance program. To be effective, the QA program must be designed to focus on minimizing potential risks to the patient and clinicians.

Objectives for this article are:

1) To specify six primary steps for implementing and maintaining an effective dialyzer reprocessing quality assurance program.

2) To describe a systematic and practical approach for compliance with AAMI/HCFA dialyzer reprocessing requirements.

3) To identify reprocessing-associated "high risk" patient problems for prevention; the typical problem sources and solutions.

Six primary steps can be taken to implement and maintain an effective quality assurance program for dialyzer reprocessing (Fig. 1).

How To Implement & Maintain A Dialyzer Reprocessing QA Program

- Understand & Comply with AAMI/HCFA Requirements
- Develop Reuse Technique-Specific Policy and Procedures
- Identify "High Risk" Patient Problems for Prevention
- Set a Validated Maximum Use Limit for Dialyzers
- Qualify/Select Appropriate Test Lab for Dialysis Samples
- Report Illness , Serious Injury or , Death, Attributable to a Medical Device, to FDA and/or Manufacturer

Figure 1

The first step in the quality assurance process is to read, understand, and comply with the requirements listed in the AAMI/ANSI Standard for Reuse of Hemodialyzers[7] and the Health Care Financing Administrations (HCFA) State Operations Manual-Provider Certification[8]. Most dialysis managers are familiar with these two documents (Fig. 2).

The AAMI/ANSI Standard for Reuse of Hemodialyzers and other AAMI/ANSI standards are revised periodically. At the time of this writing, the current reuse standard (RD47-May, 1993) is being revised. Revisions to the Standard are made by consensus of a subcommittee of the AAMI Renal Disease and Detoxification Committee. Committee members typically include nephrologists, dialysis nurses, technicians, and patients, along with representatives from the Food and Drug Administration (FDA), Centers for Disease Control and Prevention (CDC), and dialysis device manufacturers. While the AAMI/ANSI Standard is a voluntary document, compliance has become mandatory in that HCFA has incorporated the standard and additional requirements, within the State Operations/ Provider Certification Manual, as conditions for payment.

AAMI/ANSI & HCFA Requirements

- AAMI/ANSI Standard
- HCFA Manual - Provider Cert.

Figure 2

Compliance with AAMI/HCFA can be simplified by listing and summarizing the key requirements of the documents (Fig. 3). The top five requirements in Figure 3 are very similar to FDA Good Manufacturing Practices (a.k.a. Quality System Regulations) requirements for medical device manufacturers. AAMI's use of the FDA approach is consistent with the view of dialyzer reprocessing as essentially a "re-manufacturing" process.

A "Dialyzer Reprocessing Manual" is a master record collection of all specifications, policies, training materials, manuals, methodologies, and procedures, to be used, in the dialyzer reprocessing program. Development and maintenance of a "Dialyzer Reprocessing Manual" can be facilitated by the use of a pre-made checklist. An example of this type of checklist can be obtained free-of-charge by download from the Reprocessing Products Corp (RPC) website[9].

The "Reprocessing Record" is a historical log of information identifying the new dialyzer, the date of each reprocessing step, the person performing the procedure, their signature or other identifying mark, and test results of device performance and safety; e.g., copies of the reprocessing label information.

Documenting process control involves establishing written procedures with associated feedback forms, and checklists for monitoring the safety and performance of the overall-reprocessing program. Patient outcomes, reprocessing personnel qualifications, health, and training - along with equipment maintenance, performance, and supplies - are examples of areas of the reprocessing program requiring documented process control.

A complaint form and file must be developed and maintained to record complaints and incidents and associated corrective action.

Documented periodic process review is required to monitor or inspect areas of the reprocessing program that allow a facility to demonstrate on-going process control. An example of an audit schedule can be obtained free-of-charge, by download, from the RPC website[9]. A specific audit procedure, and QA forms are in the FDA publication, "QA Guidelines for Hemodialysis Devices".[10]

Occupational Safety and Health Administration (OSHA), and any additional state requirements (if applicable), must be addressed through written procedures for compliance.

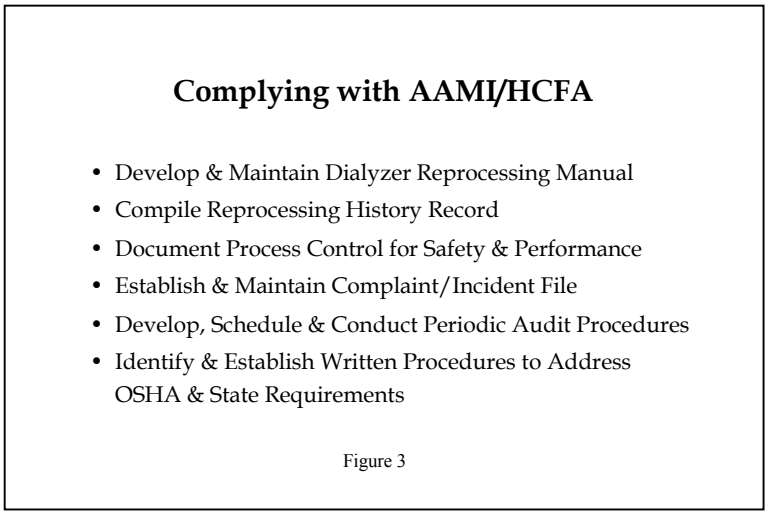

Figure 3

Step two involves developing reprocessing technique-specific policy and procedures. A written dialyzer reprocessing policy should include, at minimum, the items shown in Figure 4. In addition, a procedure for reporting illness, serious injury, or death, as required by the Safe Medical Devices Act of 1990, may be included as part of the policy.

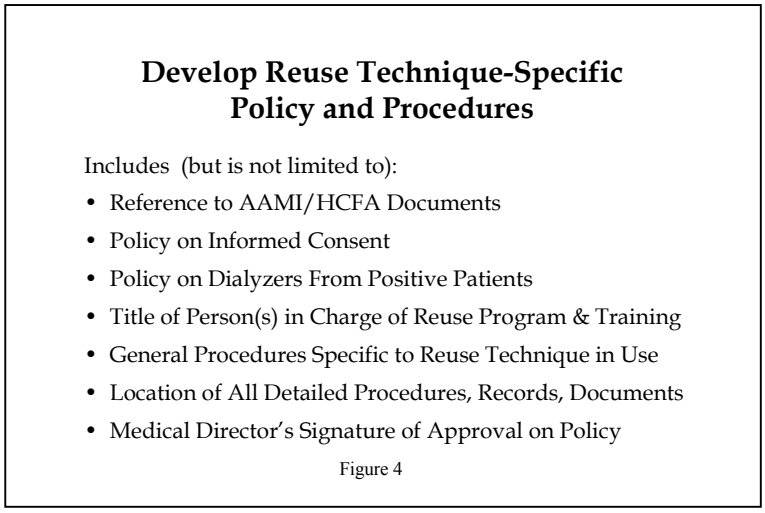

Figure 4

The term "technique-specific", used to describe the dialyzer reprocessing policy, means the type of system and germicide being used to reprocess dialyzers. Most of the systems in use are shown in Figure 5. Germicides in use include heated citric acid, gluteraldehyde, formaldehyde, and peracetic acid mixtures such as Renalin (Minntech), Peracidin (HDC Medical), and Puristeril (Fresenius).

Reuse Techniques/Systems

Renatron II

DRS-4

Echo

Also:

- Manual Systems
- Heat Disinfection with Citric Acid Cleaning

Figure 5

Step three in the quality assurance process is to identify "high risk" patient problems for prevention. Specific high risk problems that have been associated with dialyzer reprocessing are shown in Figure 6. While the list in Figure 6 is comprehensive, it is not intended to be all-inclusive.

Identify High Risk Patient Problems for Prevention

- Pyrogenic Reactions & Bacteremia
- Allergic Reactions
- Blood Leaks
- Particulate in Dialyzers
- Inadequate Dialysis

Figure 6

Typical sources of these specific high risk problems are shown in Figure 7. A reference to gray dialyzers is made, in Figure 7, as a potential patient problem. It is the author's experience that this rare color "tinting" may occur when dialyzers reprocessed with a peracetic acid germicide are rinsed with water containing residual levels of potassium permangenate. Water treatment municipalities may add permagenate to the source water under certain conditions, e.g. system flushing. No patient problems were observed. However, it would be prudent to discard the dialyzers if the tinting becomes evident.

Typical Sources of "High Risk" Patient Problems

- Excessive Endotoxin/Bacteria in Water System and/or Inadequate Germicide Concentration or Mixing
  - pyrogenic reactions & bacteremia
- Excessive Cleaner or Germicide Concentration in Dialyzer
  - allergic reactions
- Physical Stress to Dialyzer During Reprocessing Procedure
  - blood leaks
  - particulate in dialyzers
  - dialysate channeling
  - gray dialyzers due to excess potassium permanganate or manganese in H_2O
- Cumulative Clotting of Dialyzer Fibers During Treatment
  - inadequate dialysis. anti-coagulation not optimal

Figure 7

Each year the Centers for Disease Control and Prevention (CDC) release a report of their results from a surveillance questionnaire completed and returned by most of the dialysis centers in the United States (response rate was 95% in 1997)[11]. According to the 1997 CDC report[12], during the years 1989 – 1997, 19-22% of dialysis centers reported pyrogenic reactions in the absence of septicemia; possible mechanisms for these reactions include reuse of dialyzers, use of bicarbonate dialysis, and high flux dialysis. The common factor among these practices is the dialysis water treatment system.

Endotoxins and bacteria, in dialysis water treatment systems, continue to contribute significantly as the cause of patient problems[13]. Therefore, proper maintenance and disinfection of the water system is essential. Figure 8 shows a graphic example of one root source for pyrogenic reactions and bacteremic episodes. Disection of a piece of water system piping and an electronically enlarged photograph of the pipe reveals an actual bacterial biofilm that formed on the inner surface of the piping.

This is the type of problem that can develop in a water treatment system without proper design, maintenance, and routine disinfection (at least monthly). Without routine disinfection, a dialysis facility may experience normal water system cultures as biofilm accumulates. The biofilm eventually breaks free into the central water stream flow, causing a sudden catastrophic increase in bacteria delivered to all dialysis devices using the water system.

Scanning Electron Micrograph of a Biofilm of Rod Shaped Bacterial Cells and Associated Glycocalyx

Figure 8

Errors in mixing dialyzer reprocessing cleaning agents and germicides may also result in pyrogenic reactions, bacteremia, and allergic reactions.[14,15,16]

Forces that physically stress the dialyzer are present during the reprocessing procedure, pre-dialysis rinse, and throughout the dialysis treatment. Exposure to cleaners, germicides, water quality, water pressure, water flow rate, and water temperature during the reprocessing procedure, together with dialyzer temperature and pH changes at the initiation of dialysis, contribute to dialyzer material degradation.

In addition, clotting of dialyzer fibers during the treatment may result in a cumulative decrease to the patient's dialysis dose and, subsequently, inadequate dialysis.

Each of these "high risk" problems can be avoided by having an understanding of how they originate and by implementing proven quality control meaures to prevent their occurrence. An in-depth guide to solving these problems is beyond the scope and available space for this article. However, a comprehensive guide is available as a free download from the RPC website[9].

Step four, setting an appropriate maximum use/reuse limit, is one of the most important steps in the quality assurance process - yet in many dialysis centers the importance of this step is overlooked

or misunderstood. Some clinicians believe that the total cell volume (TCV) test, pressure integrity test, and visual inspection, are sufficient to guarantee dialyzer performance and therefore no maximum use limit is required. CDC data (1997) show that the mean number of maximum reuses steadily increased from 26 to 38 between 1986 and 1997[17]. During the same period, the mean number of average reuses also increased steadily from 10 to 17. The CDC data table registers the maximum number of times a dialyzer was reprocessed at 179. Given the linear increase in maximum reuses relative to increased average reuses, dialysis centers may be incrementally raising the maximum reuse number to achieve a higher overall reuse average. CDC did not publish a report in 1998. The 1999 CDC report (most current as of this writing) has been reformatted and no longer provides data on maximum use of a reprocessed dialyzer.

It is important to be aware of potential increased risk of non-detected dialyzer performance problems that may be associated with incremental increases to the maximum reuse number. A safer approach to improving reuse averages is to select and validate a maximum reuse number and not incrementally increase the maximum reuse number with time; instead, centers should work on improving each patient's reuse average up to the validated maximum use number. Ouseph, et al, have shown one method for accomplishing this task by using a pharmacodynamic model to determine heparin doses[18].

Proper assignment of a maximum use limit for reprocessed dialyzers is a necessary action critical to minimizing patient risk (Fig. 9). The maximum use number selected for each model dialyzer should be based on a documented analysis of proper dialyzer performance for each successive use. This analysis correlates directly with the requirement for documented process control.

Problems with reprocessed dialyzers have occurred that are not detected by the standard TCV and pressure integrity tests[19]. Dialyzer material degradation and dialysate channeling are examples. Therefore, the documented analysis should include verification that the maximum use number selected results in disposal of the dialyzer before problems of this type occur. In addition to the total cell volume and pressure integrity tests, which are common in reprocessing equipment, the documented analysis should take into consideration each dialyzer manufacturer's specifications for reprocessing its dialyzer.

Set A Validated Maximum Use Limit for Dialyzers

Minimizes Potential for Problems Due To:

- Undetected Change to Dialyzer Materials
  - potting compound, case, header & o-rings, fibers
- Dialysate Channeling in Dialyzer
  - non-uniform dialysate distribution around fibers
  - asymmetrical fiber bundle
  - non-correlating TCV vs. clearance
  - inadequate dialysis due to low clearances

Figure 9

As indicated elsewhere in this article, two recent large studies indicate a potential conditional increase of relative risk for patient mortality when a particular germicide is used as the dialyzer reprocessing agent. The primary germicide noted in the studies was peracetic acid. Peracetic acid (PAA) was

compared with formaldehyde and non-reuse. It would have been interesting if the study publications included data showing maximum reuse number averages associated with PAA versus formaldehyde reprocessing.

Dialysis clinicians have reported a significant increase in reprocessing averages, for dialyzers reprocessed with PAA, when compared with dialyzers reprocessed with formaldehyde[20,21]. PAA germicides contain hydrogen peroxide and are actually peroxyacetic acid compounds. Peroxide in the germicide works to denature residual blood in the dialyzer and serves as a cleaning agent during the equipment reprocessing cycle (and also during the dialyzer storage period). In addition, the denaturing action of the peroxide tends to whiten any residual blood in the dialyzer, which improves the dialyzer appearance. Even when bleach or peroxide is used as a cleaning agent for reprocessed dialyzers stored in formaldehyde, the formaldehyde dialyzer does not have the significant added storage exposure to the cleaning/whitening agent. This difference may result in an overall higher likelihood of formaldehyde dialyzers being failed for insufficient TCV or appearance when compared with PAA. This could limit the maximum use average for formaldehyde dialyzers, as these failure modes are easily identified and detected.

Peracetic acid reprocessed dialyzers overall are more likely to provide extended multiple use.[20,21] However, this extended multiple use may increase the probability of undetected reprocessed dialyzer performance failures. Dialyzer material degradation can occur gradually and may be overlooked. Risk for dialysate channeling may increase as the repeated physical forces of the reprocessing procedure work to change the symmetry or uniformity of the dialyzer fiber bundle pack. These types of problems, which are difficult to detect and are more likely with extended dialyzer use, may be the cause of, or contribute to, the increased mortality risk reported with PAA reprocessed dialyzers.

In 1997 a National Kidney Foundation (NKF) task force released a comprehensive report on dialyzer reuse[22]. One element of this report pointed out that performance changes can occur in different dialyzer types relative to the type of cleaner or germicide used and other multiple use factors. Figure 10 shows the various component parts of a dialyzer that can be altered by reprocessing, causing the changes in performance cited by the NKF task force.

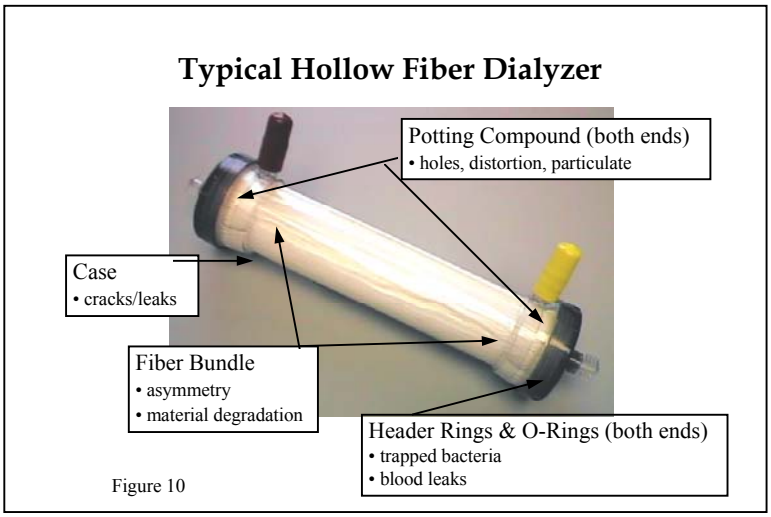

Figure 10

Placing a dialyzer in a test cycle (no patient), which reprocesses it using only water, will eventually result in a breakdown of the dialyzer materials. This fact, independent of germicide type, establishes the need for setting a validated maximum use number, which minimizes the risk of all reported reprocessed dialyzer performance problems.

Step five in the quality assurance process is to qualify and select an appropriate test lab for dialysis fluids, e.g. water, concentrate and dialysate (Fig. 11). Many high-risk problems can be prevented or more easily identified if the laboratory in use provides accurate bacteria reports.

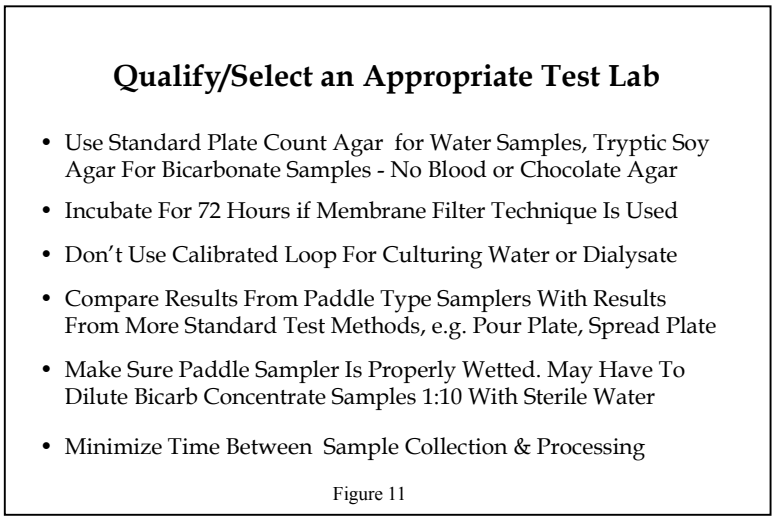

Figure 11

In 1988, Jo-Ann Maltais (PhD-microbiology) wrote a detailed guide for choosing a laboratory for dialysis fluids[23]. If the membrane filter technique is used for culturing samples, Doctor Maltais recommends incubation of the samples (especially bicarbonate samples) for 72 hours, "as the organisms often take longer to grow using this technique." It should be noted that this recommendation differs from the 48-hour incubation time listed in the AAMI RD62 draft document[24] for dialysis water treatment.

Doctor Maltais granted permission to include the guide in an earlier article this author wrote entitled, "Preventing Specific High Risk Problems Typically Associated with Dialyzer Reprocessing"[15]. The laboratory guide is an addendum to that article. The article is available from the RPC website and can be downloaded free-of-charge. Failure to follow appropriate lab procedures may result in inadequate or inaccurate bacterial test information for making clinical quality assurance decisions.

Step six involves compliance with FDA "user facility" reporting requirements. The FDA Modernization Act of 1997 modified the Safe Medical Devices Act of 1990[25] requirements. FDA newsletters describing the progression of facility user reporting requirements can be viewed on the FDA website at: www.fda.gov/cdrh/fusenews.html. Make sure a written procedure exists for reporting incidents of illness, serious injury, or death that can be attributed to a medical device (Fig. 12).
The FDA's definition of a medical device includes (but is not limited to) dialysis water systems, dialysis machines, dialyzer reprocessing equipment, cleaners, and germicides used in the reprocessing procedure, and port caps used for reprocessed dialyzers.

Report Illness , Serious Injury, or Death Attributable to Medical Device

- Safe Medical Devices Act of 1990 Requirement
- Report No Later Than 10 Working Days After You Become Aware of the Incident
- Reports of Death to FDA and to Manufacturer if Known
- Reports of Serious Injuries or Illness to Manufacturer or FDA if Manufacturer is Not Known
- User Facilities Submit Semi-annual Summary Report to FDA

Figure 12

In conclusion, a dialyzer-reprocessing program must be designed to maximize patient and staff safety. This cannot be accomplished without an emphasis on minimizing patient and staff risks. Implementation of the six steps listed in this article will minimize these risks.

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