

Quality Management for Intravascular Brachytherapy

Bruce Thomadsen

Abderrahim Chakri

University of Wisconsin – Madison

INTRODUCTION

Of procedures in which medical physicists participate, intravascular brachytherapy (IVB) forms one of the simplest and most inflexible. For much of this procedure's existence, the manufacturers of the equipment dictated the quality management for their units, and in some cases, prohibited participants in their clinical trials from performing anything additional. In this aspect, IVB differs from every other facet of radiotherapy physics, where the physics community establishes the recommended quality management programs. While simple, the procedure holds a sizable potential for harm to the patient. The medical physicist maintains the responsibility to minimize the likelihood of operational problems or dosimetric errors.

The discussion in this document concerns only the Transcatheter approach using sealed sources. Radioactive stents would have a quite distinct set of QM procedures, but the use of such stents has been halted because the clinical trials have not demonstrated their effectiveness. Trials of balloon catheters filled with radioactive fluids or gases also have been stopped, so the QM issues presented there will not be addressed herein. Finally, delivery of the radiation using radioactivity-impregnated catheters is yet in its relative infancy, and will remain for a future discussion. This discussion ignores all regulations, addressing what would be required from a safety and quality point of view.

The delivery devices considered for the Transcatheter, sealed-source approach range from incredibly simple (actually, no device) to very sophisticated high dose-rate afterloaders (HDRA). The quality management procedures appropriate for each must be customized. However, the general categories and principles apply uniformly across device line.

PRINCIPLES FOR INTRAVASCULAR BRACHYTHERAPY QUALITY MANAGEMENT

The overall goal of quality management (QM) for intravascular brachytherapy remains the same as with any brachytherapy procedure: to deliver the correct dose to the correct location – safely. The general classes of QM also follow closely that of other brachytherapy. Establishing the QM for a new procedure offers the opportunity to approach the program following the guidelines of ISO 9000: 2000. A distillation of the standard and its application to this procedure comprise the appendix.

The basic requirements to achieve the QM goals include the items on the following list. Fundamental to any QM program is verification of all important parameters, and verification that is independent whenever possible.

A. To assure delivery of the correct dose:

- 1. Verification of the source strength.** Decreasingly, the practicing medical physicist accepts source assays from the manufacturer. Two reasons for this trend include increasing ability for clinical physicists to perform verification measurements and a history of some significant errors in source strength on the part

of manufacturers. In some cases, the practicing physicist can calibrate sources better than the manufacture. IVB sources form no exception. For the beta-emitting sources, the calibration of the institution's well chamber by a Accredited Dosimetry Calibration Laboratory (ADCL) provides an assay of a source or source train as accurate as that available to the manufacturer, and only marginally less than from the National Institute for Standards and Technology (NIST). If the source carries a calibration from NIST (not just traceable to NIST), the treatment times should be derived from that calibration. If, on the other hand, the manufacturer proves a calibration *traceable* to NIST (but not *by* NIST), the institution's assay should be used.

Gamma-emitting sources, surprisingly, pose a more difficult problem. The sources used in the gamma device are the same as those used in standard brachytherapy. The assay of a single source can be accomplished with high accuracy a well chamber calibrated by an ADCL. Unfortunately, the accuracy of calibration usually decreases with a source train both due to positional dependence of the sources in the chamber and variation of the source strengths in the train. The discussion of these difficulties is beyond the scope of this document. The conclusion, however, is that if the manufacture accounts to the strength of each source in the determination of the dose rate, the manufacturer's calibration should be used. If the manufacturer uses only an average or batch value for the sources, the institution's assay is as likely to be the better estimate. NIST does not calibrate gamma-emitting source trains.

For any source type, a crude verification of source activity should be made using an autoradiograph. This test simply entails placing a catheter on a sheet of film in a paper jacket, and running the source or sources to the end of the catheter for a short time. Finding the appropriate time may require some experimentation, and depends on the source strength and the processor condition. The goal is to visualize each of the sources in a source train on the film, and see that the darkness produced by each is approximately equal. An x-ray exposure (about 60 kVp and about 25 mAs•m²) helps in this assessment as with evaluating the symmetry of the source material in a cesium needle. The films provide no quantitative information, unfortunately.

- 2. Validation of the prescription for the patient.** The unfortunate situation at the present leaves the whole nature of the prescription a function of the device used. While the American Association of Physicists in Medicine subcommittee on IVB suggested a uniform *reporting* protocol, the committee demurred with respect to suggesting a uniform method of prescribing the treatment. The current options for approved devices include specifying the dose at a fixed distance from the center of the catheter or at a fixed distance into the artery wall with geometric restrictions. In defense of forgoing a suggested uniform prescription system, the data gained in the clinical trails for each device used the manufacturer's prescription system. Thus, changing the prescription techniques likely would change the expected outcomes unless a large set of cases were studied comparing the doses specified with both a uniform and the manufacturer's systems with the clinical outcomes. For the present, the prescription as specified by the manufacturer will be considered the correct one. Since the doses depend on the geometry of the vessel (either in quantity or location), the size must be determined. Intravascular ultrasound (IVUS) currently

provided the best estimate of the vessel diameter, but remains difficult to interpret for those not performing it frequently, and relatively expensive. Much of the time, the cardiologist estimates the diameter of the vessel based on a single-view arteriogram and the size of the angioplasty balloon. While less than ideal, reality dictates that this may have to do for the present. A combination of IVUS and arteriogram would serve to verify independently the vessel geometry. Without the two methods, (and assuming neither the radiation oncologist nor the medical physicist qualify to verify the diameter on the arteriogram), the evaluation of the cardiologist will have to suffice.

The geometry information determines the dose. Currently, patient condition does not affect the dose prescribed. Whether the dose comes from a look-up table or a calculation, a second determination minimizes the very-likely error of a simple mistake. For either method, verification can be a second person also determining the dose, or having the doses in a spreadsheet program.

- 3. Determination of the treatment time.** None of the prescription protocols take into account vessel curvature. Thus, for a given vessel cross sectional geometry and source train length, the treatment times for a given dose form a simple table. Verifying the treatment time follows the same guidelines as verifying the dose – either having a second person determine the time or use a spreadsheet *in addition to* the manual calculation. (It may not be clear whether the spreadsheet checks the manual calculation or visa versa.)

The table of treatment times itself must be checked before any patient treatments. The dose rates from the calibration check (item 1 above) should be used in this determination.

- 4. Timing of the treatment.** If the treatment unit has a built-in timer, the proper operation of the timer should be checked before use in the patient, either before the patient is taken into the room, in a different room, or using shielding along the source pathway. For devices without timers, two persons should monitor the treatment time (using timers or stopwatches). The two timers, of course, provide backup in case one fails; having two persons keep the time helps prevent missing the termination time while the cardiologist explains the interesting facets of the patient's case. For treatments on the order of two to five minutes, the primary timer should notify the team of each minute left in the treatment and alert the team at the last 30 seconds, 20 seconds, and count down the last ten seconds. In that way, the secondary timer knows that the primary timer is paying attention. Failing to hear the appropriate time marks called out, the secondary timer should provide the notice. For treatments lasting approximately a half hour, Times should be announced with 10 minutes left, again with 5 minutes left, two minutes left, and then as with the shorter treatments discussed above.

B. To assure delivery of the correct dose to the correct location.

- 1. Positioning the catheter.** Radio-opaque markers indicate the treatment location along the catheter. Placing the markers in the correct location is the responsibility of the cardiologist. Unfortunately, none of the other members of the treatment team likely have the experience necessary to verify the positioning.

2. **Positioning the sources in the catheters.** When the sources move into the treatment position, they, or markers on the ends of the source train, can be visually observed under fluoroscopy. The radiation oncologist and the medical physicist both need to verify correct seating of the sources. Failure of the sources to seat properly within a few seconds is reason to withdraw the sources and test the catheter, as described below.

C. To assure the safe movements of the sources.

Misadministrations in IVB mostly result from problems with the source movement. The procedures suggested by the manufactures do not necessarily provide the required assurances; the steps below should.

1. **Check the treatment catheter for integrity and patency, and**
2. **Check the source train operation.** While quite distinct, much of these two steps may be performed together. Moving a source train into the catheter and looking for water leaks can assess the treatment catheter's integrity for water-drive systems. For dry systems, the test comes with the catheter in the patient's artery, looking for blood flowing out the catheter. The patency test assures that the source can pass to the treatment position in the catheter. While using a dummy source train for the patency test indeed checks the catheter, the actual source device remains untested in the treatment catheter. Ideally, the patency test for the catheter should also check that the treatment source device will actually pass the sources to the treatment position and back to their shielded housing. The only problem with using the actual source train for the patency check is the potential exposure to personnel and the patient. For beta emitters, the entire catheter in the packaged coil easily fits into a plastic box open on one end. One centimeter or three-eighths of an inch of acrylic suffices to stop most of the radiation from the beta sources. The gamma sources, again, prove more challenging. The 30 seconds of a typical ^{192}Ir source exposed for this check would likely expose the medical physicist to about 8 mR (80 μSv). To bring that to 2 mR would require 2 half-value layers, or about 6 mm of lead. Such a box would be heavy, but could be part of the cart that carries the source shielding. Regardless of source type, the box shielding the sources in the treatment catheter must either be sterile or have a sterile covering.
3. **Check the catheter for patency in the treatment position.** Most of the misadministrations reported for IVB occur because of failure of the sources to travel to the treatment site or return. The frequency of such incidents indicates that the patency of the catheter pathway should be tested with an inactive, dummy source prior to insertion of the active sources. Upon positioning the treatment catheter, just prior to the actual treatment, the dummy sources should be sent to the end of the catheter, the position of the dummy sources verified under fluoroscopy, and the dummy sources retracted.
4. **Check for recovery preparations.** Shortly before completion of the treatment, preparations for source recovery should be verified. For the water-driven devices this entails the connection of an adequately full syringe of water to retrieve the sources. For cable-driven sources, preparations may only require the presence of the person who pulls the sources back. Automated units require no check at this point.

5. **Check for complete recovery of the sources.** Following treatment, as with any brachytherapy treatment, the exposure rate near the treatment site should be measured with a sensitive radiation detector to check for any sources left behind. Such a check suffices for verification of source retraction for a gamma-emitting source. Beta-emitting sources could lodge in such a manner as to remain undetected by such a test. For sources not driven by automated remote afterloaders, in addition to measurements of the exposure at the patient, the source or sources require visual verification of retraction.

HDRA-type IVB units require much of the same testing as those used for general brachytherapy, in addition to the tests listed above. The addition tests include:

6. **Catheter connection verification.** The unit must be able to detect the absence of a correctly seated catheter, and not send the source out of the housing.
7. **Emergency retraction operation.** Initiation of an emergency retraction must bring the source into the housing.
8. **Treatment interrupt operation.** Interruption of a treatment must bring the source into a safe condition and allow for resumption of the treatment without loss of information or treatment time.
9. **Timer operation.** The timer must demonstrate accurate operation and termination of a treatment after the set time. During initial calibration at the time of source change the timer linearity must be assessed.
10. **Indicator operation.** All indicator lights must work properly.

The distance validation checks can be performed as with the manual systems.

APPENDIX

Requirements of ISO 9000 for Quality Management

ISO guidelines serve to assist in the establishment of quality management programs by outlining the general nature of the procedures to be incorporated. Those aspects directly relevant to IVB QM are listed below. The QM program for IVB should be integrated as part of an overall departmental QM program. For that program, other parts of the ISO guidelines apply.

General requirement for ISO 9001:2000 *Identify processes needed by the system to meet the requirements*

- Determine the sequence and any interactions between these processes.
- Map out the processes possibly in flowcharts
- Determine criteria by which the processes will be controlled and how it will be done.
- Measure the performance of our key processes as tool to continually improve them.
- Ensure availability of resources.
- Monitor, measure and analyze the key processes.

Documentation requirements

General: Quality system shall include:

- Documented statements of quality policy and quality objectives.
- Quality manual.

- Documented procedures.
- Documents required by the organization to ensure effective planning, operation and control of the processes.
- Quality records as required by the standard.

Quality manual:

Scope of the quality system including details of justification of any exclusion.

- Description of the interaction between processes.
- Documented procedures or reference to them.

Control of documents

A documented procedure shall be established to define controls for:

- Approving documents.
- Reviewing and updating documents.
- Ensuring changes and current revisions status of documents are identified.
- Ensuring relevant versions of documents are available at point of use.
- Ensuring documents of external origin are identified and distribution is controlled.
- Preventing unintended use of obsolete documents.

Control of Quality Records (QR)

QR shall be established and maintained to provide evidence of conformity of the quality system. These records remain legible, identifiable and retrievable. The procedures must exist to established controls for identification, storage, protection, retrieval, retention time and disposition of QR.

Quality Assurance Development

- Definition of the product parameter from the request of the patient and user.
- Design process (monitoring of the development regarding the parameters that can be achieved).
- Design verification (product requested during the development process are fulfilled).
- Design validating.
- Risk analysis.

Quality Assurance Production (supplier concerned)

- Definition of suitable processes and operational sequences.
- Monitoring of production processes.
- Measurements of product parameter
- Identification and Traceability.

Preventive and Corrective measures

Target: Guarantee of the conformity of all products

Analysis of production processes:

- Investigation of the causes of deviation.
- Definition of measures.

Continual improvement

Basis: Observation of production of the processes and the market.

- Request change by experiences and new realizations.
- Design modification.