

MrOS
DXA Quality Assurance Manual
for
Hologic QDR-4500
Bone Densitometers

UCSF DXA Quality Assurance Center
Department of Epidemiology and Biostatistics,
Division of Clinical Epidemiology, Box 0886

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1.0 Introduction

The purpose of this manual is to describe the DXA bone mineral density (BMD) quality assurance program for the clinical centers participating in the MrOS study. It provides information specific to the Hologic QDR 4500 and is intended as a supplement to the Hologic Users' Manual.

To use this manual effectively, it is essential that to have read and understood the entire Hologic QDR 4500 User's Manual. The study densitometry operators are required to have participated in a Hologic QDR 4500 training session and should be familiar with all instrument features and procedures discussed in the Hologic Users' Manual.

During the study, any questions regarding procedures that arise should be directed to:

MrOS Quality Assurance Center
University of California, San Francisco
74 New Montgomery St., Suite 600
San Francisco CA 94105

Telephone: (415) 597-9287

Fax: (415) 597-9213

IMPORTANT: Unauthorized changes in scanner model, software or personnel can have a large impact on the integrity of study data. If, for any reason, changes in any of these areas are anticipated, please contact the DXA Quality Assurance Center in San Francisco in advance for further instructions.

2.0 STUDY LOGISTICS

Densitometry measurements will be acquired at the Baseline Visit and the Year 5 Visit. Bone mineral density scans will be made of the Hip, PA Spine and Whole Body at each visit.

2.1 Division of Quality Assurance Responsibilities

2.1.1 Clinical center responsibilities

The clinical centers must ensure the overall quality and completeness of the DXA data and that all protocols and procedures are strictly followed. Specific responsibilities include the following:

1. Require that operators are properly trained and certified. If there are State requirements for DXA operators, these must be met;
2. Identify a chief densitometry operator to train and supervise other operators;
3. Perform and review daily QC scans and scheduled cross-calibration scans of traveling phantoms;
4. Assure that proper archiving and back-up procedures for participant scans are performed and that archives are stored securely on appropriate archiving media until the end of the study;
5. Once a month, on or about the 15th, send the following materials to the QA Center:
 - a. Printouts of plots of the daily QC data
 - b. Updated copies of participant scan and machine repair logs
 - c. Original printouts of flagged scans
 - d. Original printouts of other requested scans
 - e. Traveling optical disk with all newly acquired scan files obtained since the last data transfer
6. Reanalyze centrally reviewed scans, as requested by the QA Center;
7. Assure proper functioning of hardware/software and request service from Hologic;
 - a. Notify Hologic and the QA Center of any machine or software problems or if the QDR machine is being relocated

- b. Record machine/software problems and service on the Hologic Repair/Service/Upgrade Log
 - c. Perform 5 QC phantom scans before (if possible) and after service
 - d. Perform 5 QC phantom scans before and after machine relocation
8. Contact the QA Center with any questions or problems that cannot be dealt with in the monthly batch mailings.

2.1.2 MrOS Quality Assurance Center responsibilities

The following are the responsibilities of the QA Center:

1. Write and maintain the quality assurance manual;
2. Promptly review the QC phantom scan data received from each clinical center in order to identify surges or drifts in machine performance;
3. Incorporate new participant data into the study wide database;
4. Review certification and flagged scans and return results to each clinical center;
5. Request and review random samples of scans from each clinical center;
6. Arrange for cross-calibration of all DXA instruments using traveling phantoms;
7. Prepare quality control summary reports for MrOS Steering Committee review;
8. Identify possible sources of error, and suggest possible solutions. (**However, the QA Center will not be responsible for the solution of a hardware or software problem; that will rest with the clinical center and Hologic.**)
9. Review and evaluate special purpose phantom scans;

Any questions or correspondence regarding the manual or the technical aspects of the DXA measurements should be directed to:

Bonnie Blunt
MrOS Quality Assurance Center
UCSF Prevention Sciences Group
74 New Montgomery, Suite 600
San Francisco, CA 94105

Phone: (415) 597-9287 FAX: (415) 597-9213

2.2 Training and Certification of MrOS DXA Operators

To obtain consistent results, the densitometry operators must be aware of possible sources of error that may affect data collection and analysis. Only those operators who have been certified through Hologic training and the QA Center review are allowed to perform the scanning and analysis for this study.

Anyone performing scans for the MrOS study must meet the following requirements:

1. Read and understand both the Hologic QDR4500 manual and this manual;
2. Successfully complete a Hologic QDR4500 training course ;
3. Satisfactory review of each operator's initial scans by QA Center.

In order for an individual operator to be certified to perform scans of a given skeletal site, the first 10 scans done on study participants at each skeletal site for each operator must be sent to the QA Center for review. Original printouts of scans should be sent to the QA Center at the address listed above as soon as the first 10 scans have been completed.

It is the clinical center's responsibility to ensure that all of the above certification criteria are met as new operators are brought into the study. Since the Hologic central training sessions are held infrequently, there may be several months delay between when a new operator is hired and when certification is complete.

Certification procedures for followup measurements

To ensure a high level of quality for the analysis of the followup scans, there will be an additional certification procedure for all BMD operators involved in the study. Each QDR operator will be required to send in baseline and followup scans of the first ten Year 5 Visit participants on whom they perform densitometry in order to assess the analysis performance of each QDR operator.

Personnel not meeting these requirements may not scan participants without close supervision by a certified operator, unless specifically authorized by the QA Center.

2.3 Review of DXA Scans

Scan analysis quality will be ensured by a central review of some analyzed participant scans. Whenever scans are to be reviewed centrally:

1. An original printout of the scan should be sent to the QA Center.
2. It is the responsibility of the operator to reanalyze the scan according to QA Center comments and return a printout of the reanalyzed scan with an electronic copy to the QA Center for verification.

Procedures for compiling and forwarding scans to the QA Center are outlined in Section 5.

2.3.1 Flagged Scans

Any scans that appear unusual or difficult to analyze should be flagged for review by the QA Center. Guidelines for flagging scans are listed in Section 3.5.

Flagged scans should be sent to the QA Center monthly. Note the reason(s) for flagging on the MrOS Participant Scan Log and on the original printout, for clarification of the problem.

The printouts will be reviewed for standard positioning and analysis procedures and returned to the clinical centers with instructions for reanalysis, if appropriate. Often these problem scans have been analyzed correctly and will not require further action.

2.3.2 Random Sample and Outlier Checks

Periodically during the study, a random sample of scans and scans with exceptionally high or low BMD (outliers) will be reviewed by the QA Center. In the initial phases of the study, a relatively large number of scans will be checked to verify site performance. These checks may result in requests for reanalysis by the QA Center.

3.0 DXA Scan Acquisition and Analysis

Standard scanning and analysis procedures for the hip, spine and whole body bone density measurements are described in detail in the Hologic QDR 4500 Users' Manual. Some of the information from the Hologic manual is repeated in this manual for emphasis. Please note, however, that some of the scanning evaluation protocols for this study differ from those detailed by Hologic.

Generally use the default Fast Array for all participant scan acquisition. An exception may be made for large participants if the Array (medium) mode provides a better quality scan. It is not possible to give an exact cutpoint. It is suggested to use Array when the participant weighs 170 pounds or more or the anatomy being scanned is very thick. The decision to use Array rather than Fast Array may be made at the discretion of the operator and Array may be used without first trying Fast Array.

3.1 Participant data

This section describes in detail the specific procedures to be conducted for the MrOS study with respect to entering the patient biography, scanning the participant and analyzing the scans.

Be sure to completely fill out the MrOS Bone Density Form (teleform) (see Appendix B) before and after scanning the participant.

3.1.1 Patient Biography

An example of the PATIENT BIOGRAPHY screen for a participant with last name 'SMITH' at Birmingham is shown in Figure 1.

DOB, Sex, Weight, Height and Ethnic fields should be entered as described in the Hologic manual. It is important that the DOB match the study records and that the weight and height be updated with each visit.

Patient Name Field: Enter the participant's last name, comma, then first name. Use capital letters.

Patient ID Field: The enrollment ID consists of a 6-character combination of the clinic letter code and the participant number. **It is the single most important piece of information associated with each participant and must be entered precisely.** Consider the sample participant discussed above. Suppose the clinic ID is BI (Birmingham) and the participant number is 1301, then Figure 1 demonstrates the correct method for entering the study ID within the Patient ID field.

The following are the clinic letter codes and participant numbers that will be used for the MrOS study:

Birmingham	BI0001 – BI1500
Minneapolis	MN1501 – MN3000
Palo Alto	PA3001 – PA4500
Pittsburgh	PI4501 – PI6500
Portland	PO6501 – PO8000
San Diego	SD8001 – SD9500

Comment Field: Please enter the number (1 or 5) corresponding to the particular visit in the "Comment" field. Use 1 for baseline and 5 for the Year 5 Visit.

Scan Code field: Please enter the **MODIFIED** MrOS staff ID code of the DXA operator performing the scans. The modified staff ID code consists of the four character staff ID issued for the MrOS study, minus one of the first two letters. This allows the staff ID code to fit into the three character space of the Scan Code field. For the example in Figure 1, the operator at Birmingham has staff ID code B03.

The following are the staff ID codes that will be used for the MrOS study:

Birmingham	B01– B99
Minneapolis	M01 – M99
Palo Alto	A01 – A99
Pittsburgh	I01 – I99
Portland	O01 – O99
San Diego	S01 – S99

Ref MD Field: Enter MrOS

Be sure to use zero (0) and not the letter "O" when entering numerical data into the Patient Biography fields.

Patient Biography Information

Name: SMITH, JOHN

Soc Sec:

Pat ID:BI1301

Comment: 1

Scan Code: B03

Zip:

DOB: 10/20/30

Sex: M

Weight: 160

Height: 5' 9"

Ethnic: W

Ref MD: MrOS

Figure 1. MrOS Patient Biography Screen

3.2 Hip Scans

3.2.1. Hip Acquisition

1. Refer to the Bone Density Form (teleform) (see Appendix B) to determine which hip to scan. The **RIGHT hip is the preferred** hip unless it has hardware. If no hip scan can be performed, the participant is not eligible for the MrOS study.
2. No metal or plastic object should remain in the scanning area. Check for jewelry, coins or other objects in the hip pockets, zippers, buttons, rivets, belts or any other clothing fasteners, as well as hip and back braces.
3. Keep the participant's hands out of the scanning area by placing them well away from the hips.
4. Ensure rotation of the hip by holding the knee and the ankle when positioning the leg. Optimum positioning of the leg is most important to achieve a consistent projection of the femur. Scan the other side if you cannot rotate the foot inward due to pain.
5. After proper rotation attach the leg to be scanned to the angled foot block supplied by the manufacturer.
6. The participant should be made as comfortable as possible to reduce the chance of unwanted movements. Use a pillow for the head and a small pillow under the knee of the leg not being scanned. Maintain the participant at a comfortable body temperature for the duration of the scan.
7. Instruct the participant to remain still until the end of the measurement. Make sure that the leg is not moved during the scan. Flag any scans in which the participant has moved and has not been rescanned.

3.2.2 Hip Analysis

Global Region of Interest The procedures outlined in the Hologic Manual are to be followed. The points listed below are for emphasis.

1. The lateral side of the global ROI should be at least 5mm (5 lines) beyond the outer edge of the greater trochanter to provide sufficient soft tissue for analysis, although it should not extend outside the participant's body.
2. The bottom edge of the global ROI should be at least 1cm (10 lines) below the lesser trochanter to provide sufficient soft tissue for analysis.
3. In order to facilitate the use of hip axis length software, the top and medial edges of the ROI should be expanded past the acetabulum to include the medial edge of the pelvic bone.
4. In the event that the global ROI must be expanded to allow complete filling of the bone edges (see below) in low BMD participants, all edges must be at least two steps away from the border of the scan field. This will be important when the baseline scan is used with the COMPARE feature on the followup scan analysis.

Bone Edges If the bone edges are not properly determined by the analysis program, increase the size of the global ROI by first moving the top border up 10 lines further from the femoral head, then by moving the medial border 10 lines further out, if possible, to include more soft tissue in the analysis. Repeat as needed. Do not move the bottom or lateral border. Do not fill in bone edges manually unless absolutely necessary. The software will automatically fill any "holes" within the bone. Occasionally, the bursa or tendons surrounding the greater trochanter can be calcified. This will produce "knobs" that can merge with the trochanter and throw off the automatic placement of the four regions. Expanding the global ROI will not always separate these from the trochanter and they will have to be manually excluded. Flag for review by the QA Center any cases in which you manually alter the bone edge.

Femoral Midline Unevenness (notches) in the upper or lower edge of the femoral neck can throw off the femoral midline so that it does not run down the center of the neck. This will in turn cause the femoral neck box to twist. If the midline looks like it might be off or the box is twisted, it may be necessary to adjust the bone mask (e.g.

filling in neck notches) in order to obtain appropriate positioning of the midline. The position of the midline itself should not be altered. If you have made changes to the scan such as filling in bone in order to alter the midline, or if the midline still seems off, please flag these cases for review by the QA Center.

Femoral Neck Box If the default neck box provided by the Hologic program looks reasonably placed, leave it unchanged.

1. Whenever possible, use the maximum width of the neck box (default). The neck box should be perpendicular to the neck axis. Always anchor the neck box at the inflection, or "turning point" of the greater trochanter. On some scans, it will be necessary to lengthen the neck box in order to get correct placement of the neckbox. If the maximum area of the neck that can be covered by the femoral neck box is less than 1 cm^2 , the participant should be rescanned with special care taken to improve the rotation and degree of adduction of the leg. Since such a narrow neck box would be only 2-3 lines wide, you will only rarely have a problem with this constraint.
2. If the area of the neck region is less than 2.5 cm^2 , attempt to increase the width of the neck box to the maximum possible while still avoiding inclusion of the trochanter, ischium, or femoral head and acetabulum. In order to obtain maximum size of the neck box, the ischium may be deleted (see 4).
3. If the default neck box partially extends into the trochanter, or femoral head and acetabulum, adjust its location or size while maintaining the maximum possible area.
4. The Hologic software is sometimes unable to provide an appropriate placement of the neck box and other regions. This can occur if the projected neck axis is too short or the neck is too close to the ischium. Soft tissue between the neck and ischium will be read as bone, and the automatic placement of the femoral midline will fail. If this happens, use the procedure described in the Hologic manual for deleting the bone of the ischium. Deleting this will not adversely affect the analysis, as this bone is not included in the reported regions of interest.

Ward's Triangle The Hologic software should place the square marking Ward's triangle adjacent to the femoral neck box. In participants with low BMD or short femoral neck projections, the Ward's Triangle box may be misplaced considerably. If

this happens, follow the instructions in the Hologic manual to modify the search region and flag the scan for review.

Trochanteric Line The trochanteric line should intercept the bone edge just below the lateral aspect of the greater trochanter. There is no need to correct minor deviations (up to about 3 pixels).

3.2.3 Hip Reanalysis

Always use 'Control-END' to confirm the general ROI of a hip scan for reanalysis of a baseline scan. All regions of interest will be recalculated. Ward's triangle and trochanteric line will be placed independently from the previous analysis. This procedure is absolutely necessary when you reanalyze your scans, to delete the ischium or filling in notches, for example. After accepting the general ROI proceed with the analysis of the hip scan as you did before.

3.2.4. Hip Followup scans

Load the baseline scan onto the hard disk. Display this baseline evaluation using the COMPARE feature along with the current scan to be analyzed. It is important to realize that proper comparison of a followup hip scan to its baseline depends upon maintaining the identical size and relative position of the region markers. Vertical or horizontal shifts of these regions by one or more pixels can greatly alter the final values of the analysis.

Care should be taken **NOT** to create a new biography when the participant returns for repeat measurements

The following fields should be updated in the patient biography during the followup visits:

- ⊙ Comment field – enter the correct study visit code
- ⊙ Operator scan code
- ⊙ Weight
- ⊙ Height

Global Region of Interest

1. The width and height of the global ROI must be the same as that used on the baseline.
2. The dotted lines from the baseline defining the bone region should overlay the followup as closely as possible. Occasionally there are small changes in adduction and rotation of the leg that were not eliminated by rescanning. The region surrounding the neck should have the best fit.

3. If the global ROI cannot be moved to the appropriate position because it is too large, the baseline scan will have to be reanalyzed with a properly reduced global ROI. Then the followup should be analyzed comparing it to the reanalyzed version of the baseline. Flag cases in which the baseline had to be reanalyzed.
4. Use **<Control> <End>** to accept the global ROI and bone mask.

Bone Edges If the bone edges do not fill in properly on the followup analysis, first the baseline will have to be reanalyzed with a larger ROI, and then proceed with the comparison scan analysis.

Femoral Midline Unevenness (notches) in the upper or lower edge of the femoral neck can throw off the femoral midline so that it does not run down the center of the neck. This will in turn cause the femoral neck box to twist. If the midline looks like it might be off or the box is twisted on either the baseline or followup scan, it may be necessary to adjust the bone mask (e.g. filling in neck notches, deleting the ischium) in order to obtain appropriate positioning of the midline. The position of the midline itself should not be altered. If you have made changes to the scan such as filling in bone in order to alter the midline, or if the midline is still off, flag these cases for review by the QA Center.

Femoral Neck Box If the current location is optimally matched to the location of the neck box of the baseline analysis, use it unchanged.

1. If the current location is not optimally matched to the location of the neck box on the baseline, adjust the current region to achieve maximum correspondence. The size of the neck box must be the same on both baseline and followup.
2. If the current location cannot be satisfactorily adjusted while maintaining the same sized neck box, reanalyze the baseline within the constraints outlined above.
3. It is most important to have the neck box location and size correspond as closely as possible. If you cannot get the neck boxes to match, flag the scan for review by the QA Center.

Ward's Triangle If the Ward's triangle box appears on the followup scan in a significantly different position than on the baseline, or if after reanalysis of the baseline its location is different than that of the original baseline placement, flag the scan for review by the QA Center.

Trochanteric Lines The trochanteric line should intercept the bone edge at the same point on all scans. Matching is easily done during the compare analysis, especially since you will have the baseline to consult during the compare.

3.3 Spine Scans

The HOLOGIC Operator's Manual should be consulted for the proper spine scanning and analysis procedures. Clarifications and exceptions for the MrOS Study are noted below.

3.3.1 Spine Acquisition

Participant set-up

Baseline and followup

1. Do not scan the spine of participants who have metal rods and pins throughout the L1-L4 area. If metal rods and pins affect only one or two levels, scan and analyze by deleting the affected levels. Flag such scans for review.
2. No metal or plastic object should remain in the scanning area. Check for jewelry, zippers, buttons, rivets, belts, hooks or any other clothing fasteners, as well as hip and back braces.
3. Lower any heavy or tight clothing so that nothing obscures the scanning area.
4. Follow the instructions for participant positioning outlined in the Hologic Manual. Verify that the participant's spine is aligned with the DOTTED line on the scanner table (slightly to one side of the table center).
5. Use the Hologic positioning block under the participant's knees to reduce lordosis. Always use this same block and block position for all future scans.
6. Keep the participant's hands out of the scanning area by placing them over or behind the head or at his side but out of the scan field.
7. The participant should be made as comfortable as possible to reduce the chance of unwanted movements. Use a pillow for his head and elbows if necessary. Ask the participant if he will be able to lie comfortably for the duration of the examination.
8. Include 5 to 10 lines of the iliac crest in the AP scan. Terminate the scan if positioning is incorrect; reposition the participant and restart the scan. If necessary, perform a preliminary scan to verify participant positioning.

9. Observe the scan acquisition on the screen. Use the rescan feature (F3 key) freely following the instructions in the Hologic manual for repositioning the scan starting point (blue arrow) and realigning the scan center line within the red limits. It is imperative that the spine is well centered and that part of the iliac crest is clearly visible.
10. Scan from the middle of L5 (include a portion of the iliac crest for reference) up to the middle of T12, so that you will include all vertebrae from L1 to L4. Be sure to collect sufficient data for accurate identification of vertebral levels. If you are unsure of the levels, acquire data through T11.

Followup for Year 5 Visit

Before scanning the participant have a printout of the baseline scan available. Refer to the baseline printout for positioning of the participant and scan modes selected; this is to ensure consistent scanning of the same area. Careful positioning and visual comparison of the current scan with baseline are essential for producing precise measurements. Use the rescan feature as soon as any positioning errors are detected during the current scan.

3.3.2 Spine Analysis

1. Use the default width parameters.
2. Adjust the ROI (Region of Interest) to **include L1 – L4**.
3. Adjust the ROI and intervertebral lines to accommodate scoliotic spines.
4. *Labeling of Vertebrae.* Label the vertebrae using the iliac crest (and the ribs, if visible) as landmarks. Most individuals have only 5 lumbar vertebrae, although it is not uncommon to see 6 in some participants; L5 will be at or below the iliac crest, which is why the iliac crest is used as a landmark.
5. *Exclusion of Vertebrae.* Crush fractures are to be excluded from the analysis. Confirm that your inter-vertebral spaces are properly adjusted. Flag all scans that have deleted levels.
6. *Filling and Deleting Bone.* After the software has calculated the bone mask (yellow area), fill in any remaining obvious gaps or holes in the vertebral bodies. This may sometimes require altering the bone edges. Please flag scans on which you altered the bone edges.
7. *Bone Edges.* If there are no obvious gaps or holes, do not alter the bone edges. Sometimes the transverse spinous processes or closely adjacent ribs can alter the

appearance of the bone edge. To achieve optimal precision, most of the time it is best to let the computer define the bone edges.

Follow up

Load the MrOS baseline scan onto the hard disk. Display this baseline evaluation using the <COMPARE> feature along with the current scan to be analyzed.

1. *Brightness and Contrast.* The MrOS population may exhibit notable variations in weight, spine condition, and spine anatomy, any of which can result in scans that are difficult to analyze. Adjustments to the brightness and contrast will frequently be necessary to improve the appearance of the image.
2. *Global Region of Interest.* Use the same ROI as used on the baseline scan. If the yellow ROI box cannot be adjusted from the baseline to followup scans, it may be necessary to reanalyze the baseline examination. Be certain that the vertebral levels correspond between baseline and follow up; mismatched levels can give the appearance of shortening or lengthening of the spine on follow up. Flag any alterations. **Never change the width of the global ROI on the followup scan.**
3. *Inter-vertebral Spaces.* It is most important that the inter-vertebral space markers of the followup scan correspond as closely as possible to those of the baseline scan. The <COMPARE> feature will generate the baseline vertebral spacing automatically. A slight manual adjustment may be necessary to place the line markers at the same level between the vertebrae. Large discrepancies in spacing may indicate that either the baseline or followup scan has had its inter-vertebral spaces misinterpreted or that a crush fracture has occurred.
4. *Labeling Vertebral Levels.* Match corresponding vertebral levels from baseline to follow up. Look carefully at the darker low density features at the inter-vertebral spaces and count up from the pelvic girdle to determine levels. If levels were mislabeled on the baseline scan (e.g., L2 was called L1) and the baseline must be reanalyzed for another reason, correct the level numbers. Otherwise, flag any scans with uncorrected levels for review by the QA Center.
5. *Crushed Vertebrae.* If a vertebra appears to have crushed since the baseline scan, both the crushed followup vertebra and the normal baseline vertebra must be excluded from these analyses. This will require reanalysis of the baseline scan. Flag these scans.
6. *Bone Edges.* Do not alter the bone edges unless there are obvious gaps or holes. Flag all scans where bone adjustment is necessary.

3.4 Whole Body Scans

The HOLOGIC Operator's Manual should be consulted for the proper whole body scanning and analysis procedures. Clarifications and exceptions for the MrOS Study are noted below.

3.4.1 Whole Body Acquisition

When performing whole body scans, attention has to be paid to the following points:

1. Have the participant remove all clothing, including shoes, and dress them in a hospital gown. Check that no metal or plastic objects remain in the scanning area. This includes hair clips and pins, snaps, zippers and buttons. Have participant remove any jewelry, earrings, bracelets, watches, or rings.
2. Position the participant in the center of the scanning table with their head just below the head of the table. *It is extremely important that the participant is correctly positioned on the exact center of the table.* The arms should be separated from the sides of the body with the hands placed palm down, within a few centimeters of the table edge.
3. Place a loop of tape around the top of the feet so that the feet are slightly inverted - this will help to prevent motion during the scan and create a separation between the tibia and fibula.
4. Verify that the participant is aligned with the scanner axis (solid line on the table). If during scanning it is apparent that part of the participant's body lies outside the scan field, restart the scan.
5. The participant should be positioned as comfortably as possible since this reduces the chances of unwanted movements. In general, try to avoid the use any pillows or blankets. If the participant feels uncomfortable in that position, you may use pillows for the head only after the upper half of the scan is done. You may then carefully place a pillow under the head of the participant without causing motion artifacts. This procedure should be practiced with the participant before scanning. If the participant cannot lie flat at all without the aid of a pillow (due to kyphosis), use a radio-lucent pillow.

6. If the participant is very tall, try to include their feet in the scan by placing their head near the very top of the table.
7. Instruct the participant not to move until the end of the measurement.

3.4.2. Whole Body Analysis

Baseline

1. Locate the horizontal shoulder line just below participant's chin.
2. The vertical shoulder lines should bisect the shoulder joints and separate the arms from the trunk. Avoid including any body soft tissue in the arm ROI.
3. Align the spine ROI with the curvature of the spine, if possible. Divide the spine at the T12-L1 disc space.
4. The horizontal line above the pelvis should be just above the iliac crest. The angled lines defining the pelvic triangle so that they bisect the femoral neck.
5. The vertical line between the legs should run between the participant's feet and evenly divide the legs. The lateral leg lines should be moved to include as much of the thigh soft tissue as possible without crossing the hands.
6. Sub-region cut line placement should be such that left/right symmetry is maintained i.e. placement of lines on the left side of the body should match those on the right.

Followup

For evaluations of followup measurements, display the baseline evaluation using the COMPARE feature and compare it to your current image on the screen.

Match the location of the region markers as closely as possible to the baseline measurement. Optimally matched in this context means that the markers should be at the same position between the body regions as on the baseline image.

If adjustment cannot be done satisfactorily, it will be necessary to reanalyze the baseline scan. If it is necessary to reanalyze the baseline measurement, all subsequent followup measurements should be reanalyzed using COMPARE.

3.5 Scan Flagging Criteria

General

- Scan has unusual appearance or is difficult to analyze
- Any of the following in scan field (either in the bone or soft tissue)
 - Unusual anatomical variations
 - Surgical hardware
 - Participant motion during scan
 - Superimposed buttons, pins, zippers, pacemakers, vitamin pills, etc.
- ROI used on followup is different size than used at baseline
- Bone edges have been altered in any way
- Followup scans cannot be reasonably matched to baseline analysis

Hips

- Femoral midline is not aligned and cannot be corrected by following the analysis procedures as outlined in the MrOS manual
- Neck box width reduced from default
- Ward's triangle persistently located outside of Ward's region - difficulties in redefining search region
- Analysis program repeatedly fails to place regions appropriately - major operator interaction required for analysis

Spine

- Participant motion without rescanning (these scans are extremely susceptible to motion artifacts)
- Significant changes in positioning between baseline and follow - up scan.
- Unable to fit both arms in scan field

3.6 Excessive Bone Loss Procedures

Procedures for excessive bone loss will be determined and distributed before the first followup visit.

4.0 Scanner Quality Control

Monitoring of machine performance throughout the study is the joint responsibility of the clinical centers and the QA Center. The following table lists the quality control procedures and schedule.

Quality Control Scanning Schedule

Phantom	Scanning frequency
Local Hologic Tissue Bar	1 time/week
Local Hologic Spine Phantom	Daily (at least 3 times/week)
Local Hologic Hip Phantom	2 times/week
Local Hologic Whole Body Phantom	3 times/week
Whole Body Air Scan	1 time/week
Hologic "Gold Standard" Hip, Spine and Block phantoms	To Be Determined

4.1 Phantom Scans

Perform the spine and hip QC phantom scans as outlined in the Hologic manual, Quality Control Chapter. **Be sure to scan the hip phantom in Array mode, not the default Fast Array mode** (Fast Array hip scans cannot be added to the QC database). The results of these scans should be reviewed locally for abrupt changes in machine performance and the results sent to QA Center once a month.

Whole body quality control consists of Hologic whole body phantom scans, whole body air scans, and tissue bar scans. The Hologic whole body phantom comes with

instructions from Hologic and there are supplemental instructions in Appendix A. The instructions for the whole body air scans are in section 4.2 of this manual. The tissue bar comes with instructions from Hologic.

Points of procedure to note:

1. Create only one patient biography per phantom. There should be a biography for the Spine, Hip and Whole Body phantoms. Avoid duplication of phantom biographies by using the patient menu to select the appropriate biography prior to scanning the phantom.
2. Use the following instructions to create the phantom biographies. The phantom serial number is on the phantom label. It may have letters in front of the numbers. If this is a new biography, put in both letters and numbers. If you are checking an existing biography that only contains the numbers, that is acceptable. If an existing biography contains a site identifier, that is acceptable, but new biographies will not have a site identifier.

The NAME field contains the type of phantom and the phantom serial number (indicated by XXXX):

Spine Phantom #XXXX

Hip Phantom #XXXX

Whole Body Phantom #XXXX

The PAT ID field contains the phantom serial number (indicated by XXXX):
#XXXX

3. Scan each phantom on top of the pad. Ensure alignment with the scanner axis by using the laser cross - hairs.
4. Add the spine and hip phantom scan data to the QC database immediately after completing scanning and analysis. See the Hologic manual, Quality Control Chapter, section "Adding Data to QC Database". Note: the Whole Body phantom and Whole Body Air scan data can not be added to the QC database.
5. To start using the hip phantom, scan the phantom four times a day for five days (20 scans). **Be sure to scan the hip phantom in Array mode, not the default Fast Array mode** (Fast Array hip scans cannot be added to the QC database). See the Hologic manual, Quality Control Chapter, section "Setting Up a New QC Plot

(Graphs)". Follow the directions to set up the mean and limit lines for the hip QC plot. After the set up is done, scan the hip phantom two times a week.

6. Use the plot feature to verify that the spine and hip phantom BMD, BMC and AREA values of your scanner are within normal limits. It is best to plot at least one year of data. If the most recent scan falls outside the limits, reposition the phantom and repeat the scan. If the second scan also falls outside the limits and/or the CV of the BMD exceeds 0.60%, contact both Hologic and the QA Center.
7. After the spine and hip phantom scans have been analyzed and added to the QC database, delete the scans from the hard drive. Note: the Whole Body phantom scans should be archived to the clinic optical and copied to the traveling optical disks before being deleted from the hard drive.
8. Check the system drift weekly by pressing <R> while viewing the plot. The slope of the calculated regression line should be within the range of the standard deviation shown. If the drift is greater than the standard deviation, contact both Hologic and the QA Center.
9. Generate a printout of the daily phantom plots (BMD, BMC and AREA for hip and spine) once a week on your designated "QC day." This will facilitate detection of long-term drifts as well as short-term inconsistencies. Store these plots in a QC log book.
10. Original printouts including the scan results of the most recent phantom QC plots (BMD, BMC and AREA for hip and spine) are to be sent to the QA Center for review monthly. The date range for the plots should cover the previous 12 months to the present.
11. Perform a dBarchive at least once a week and store at the clinical site. Disks may be rotated monthly.
12. Follow these procedures for the Whole Body phantom:

Scan and analyze the phantom three times a week according to the instructions provided by Hologic and Appendix A of this manual.

COPY the whole body phantom scans to the traveling optical disk, then ARCHIVE to the clinic optical before deleting scans from the hard drive.

The QA Center will retrieve the scans from the traveling optical, plot the desired variables, and notify the clinical centers of any problems.

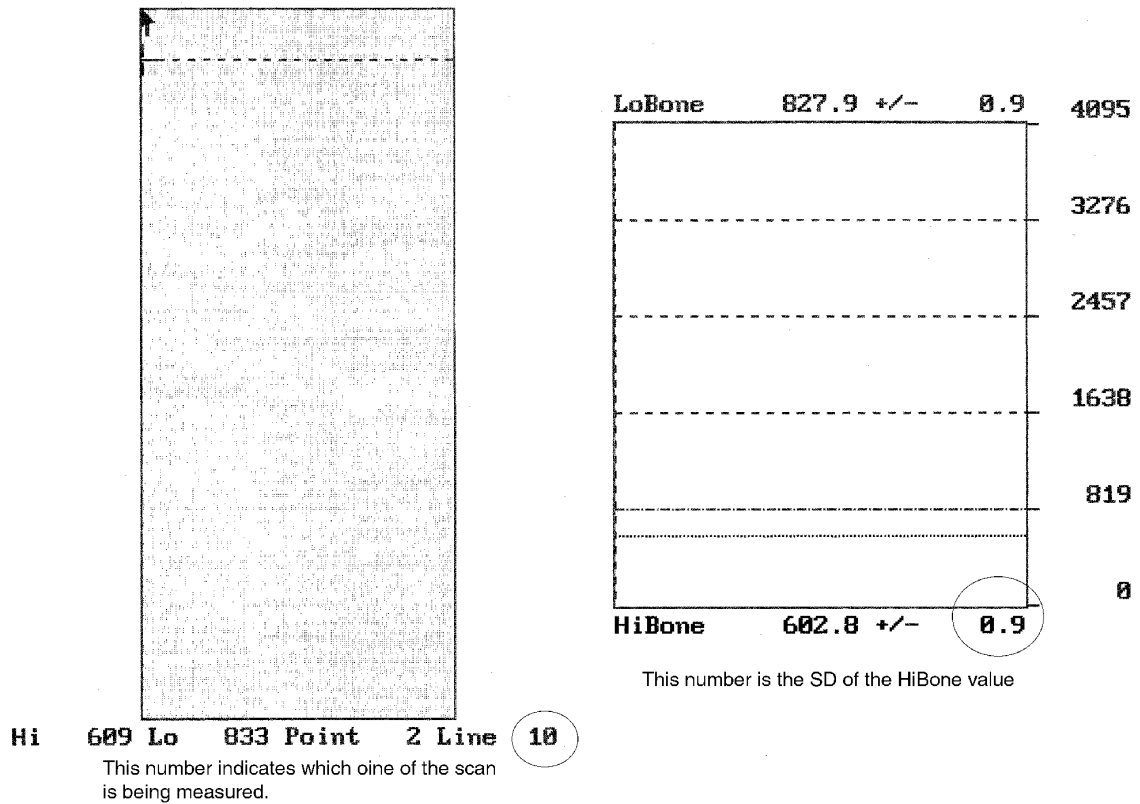
4.2 Whole Body Air Scan for the QDR 4500

A Whole Body scan of “air” (i.e. nothing on the table but a clean pad) should be performed once a week.

The “air” scan will assess the proper functionality of the QDR 4500 scanner and indicate any potential problems with the x-ray beam, if present.

1. Clear the entire tabletop of any objects and clean the pad of any debris. Only the table pad should remain on the table. This is critical since the test can detect items as thin as a single piece of Scotch tape.
2. Enter a Patient Biography with **WB AIR QC SCAN** in the Name field. Enter the **system** serial number in the Pat ID field. Leave the remaining fields blank. Press <F10> when completed. Please be certain to use this biography for all future WB air scans.
3. Perform a scan by choosing “whole body” from the Scan menu. Scan the entire length of the table. Do not interrupt the scan; perform a complete scan.
4. With the air scan selected, <ESC> to the Main Menu. Choose the UTILITY option and press <ENTER>. Then choose SERVICE and then PLOT. A blank image will appear. Press the <PgDn> key once to move to line 10.

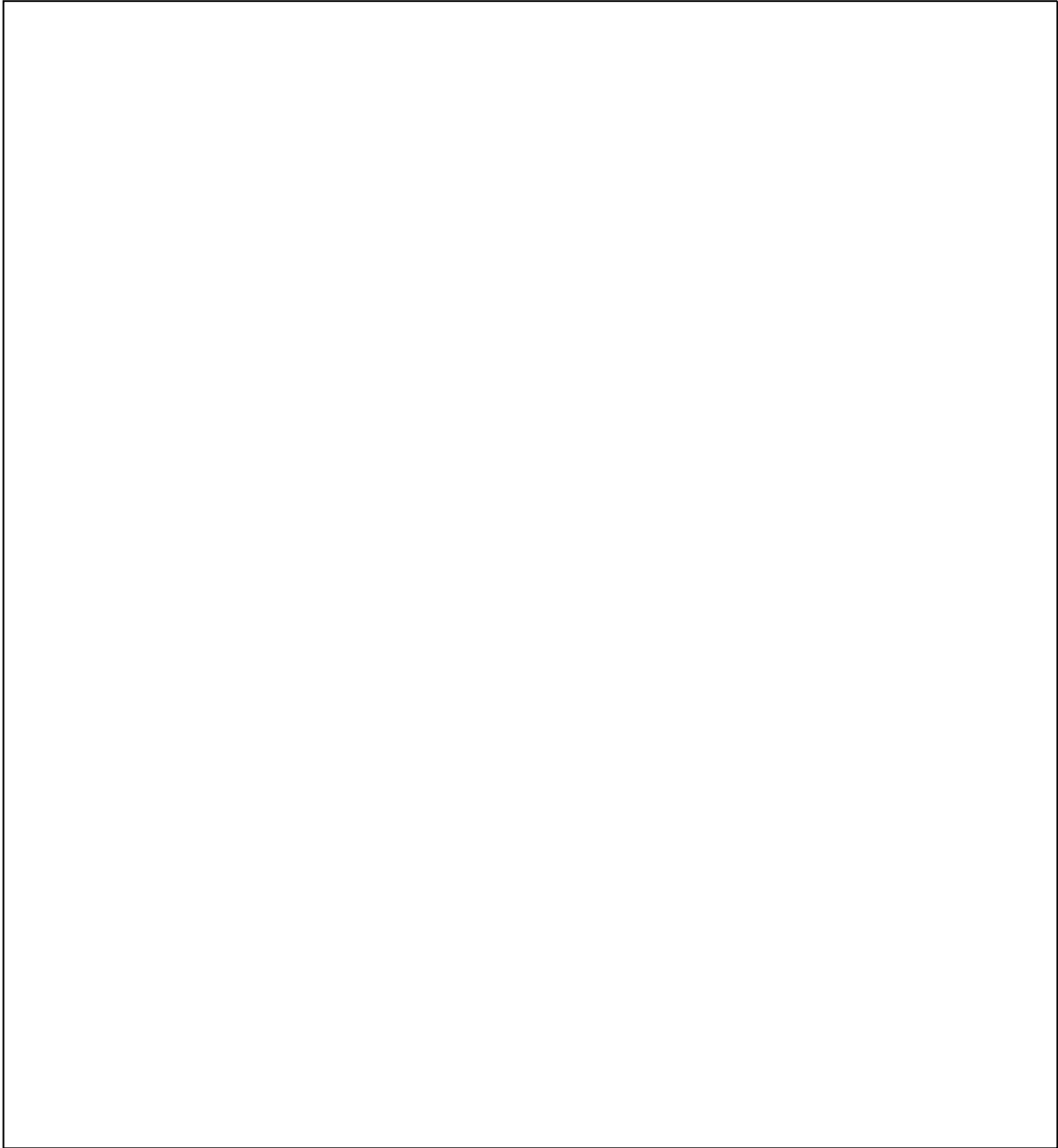
The image will appear along with a graph. At the bottom of the graph an indicator of the reference wheel segment that produced the data will appear along with an attenuation value +/- a SD (Standard Deviation). See diagram below.



For example:

HiBone 602.8 +/- 0.9

The last value, 0.9, is the value we want to record. It represents the SD of the air values across a scan line. The value should not exceed 2.0 units. Use the <DOWNARROW> key to view (9) additional lines to obtain a better estimate of the SD. Record all 10 SD values for HiBone for lines 10 through 19 on the worksheet on the following page. Please make photocopies of the blank worksheet for your use.



5. Press the <ALT><PRINTSCREEN> keys to obtain a hard copy of the plotted data. If this does not work on your scanner, do not print the data. COPY the WB AIR QC SCAN to your traveling optical and archive to the clinic opticals. Delete the air scan from your hard disk.

6. **IMPORTANT:** In the event that the SD exceeds the limit of 2.0 units, immediately fax the worksheet to Eddie Yapchian at Hologic (FAX 781/ 890 – 0863) and to Bonnie Blunt at UCSF (FAX 415/ 597 – 9213).

4.3 Cross-Calibration of Scanners

In order to assess accurately the absolute variations in scanner performance between clinical centers, periodically throughout the study phantoms will be either mailed or brought to each of the field centers and scanned. The Hologic hip, spine and block phantoms will be used. A detailed protocol will accompany the phantoms.

4.4 Machine, Software, and Service Problems

If your machine needs to be repaired or if any adjustment has to be made that possibly might affect your data:

1. Do a dBarchive before any work is done on your QDR.
2. If possible, contact the QA Center before the repairs or adjustments are made to find out whether additional measures are required.
3. Perform 5 scans of the Hologic daily QC spine phantom before (if possible) and after the repairs or adjustments are made.
4. Send the repair technician's notes and a copy of the completed Hologic Repair/Service/Upgrade Log to the QA Center with the monthly data transfer. The log should contain complete information on all repairs and upgrades done on your machine. Please keep a repair log with your machine.

4.5 Hardware/Software Change Control

Unauthorized hardware/software changes must be avoided. If for any reason you think you have to change the hardware/software, or your Hologic service representative recommends a hardware/software change, contact the QA Center before any changes are made.

Future hardware/software upgrades will be checked by the QA Center in conjunction with Hologic technical support personnel to assure that the upgrade will not adversely affect the study. Authorized upgrades must be cleared by the QA Center before installation at the clinical centers.

Record hardware/software upgrades on the Hologic Repair/Service/Upgrade Log.

5.0 Data Management

5.1 Hard Copies of Scans

The clinical center is responsible for maintaining original hard copies of all scans performed during the study. Keep the original printouts in the participant's scan printout folder. The following printed reports are needed for each scan:

Proximal femur: Print the standard report.

PA Spine: Print the standard report.

Whole body: Print the BMD and body composition reports (2 pages).

5.2 Electronic Scan Archive

Each clinical center works on a four optical disk system, two clinic opticals and two traveling opticals. Both clinic optical disks and one traveling optical are updated at the end of each day. The other traveling optical may be in transit between the QA Center and clinical center. Please be sure to re-archive any scans that you reanalyze after you have completed the reanalysis. In order to use the optical disks efficiently, do not save or archive scans individually. Saving scans in batches (e.g. at the end of a day) will ensure the longevity and efficient usage of the optical disk space. The QDR software will give a warning message when optical capacity has been reached. Fill side A of the disk first, then fill side B. (See the Hologic User's Manual for detailed instructions.). One clinic optical should be a dedicated MrOS optical, used only for archiving scans acquired for MrOS.

Scans to be archived **each day** to the clinic opticals and traveling optical disks include:

1. All new participant scans acquired since the last archive was performed;
2. All scans that have been reanalyzed since the last archive. Note that if a scan needs to be restored and reanalyzed for any reason, it will need to be re-archived.

Clinic opticals will remain at the clinical center at all times. The traveling opticals will be sent back and forth between the clinical center and the QA Center.

The clinical centers are responsible for following the archive schedule and for keeping the optical disk archives safe until the end of the study.

5.3 Transfer of Data to the MrOS Quality Assurance Center

The following items are to be sent to QA Center by the 15th of each month:

1. QC PRINTOUT. Send a printout of the most recent plots of the QC database (spine and hip - BMD, BMC and AREA). The plots are reviewed at the QA Center and problems are reported back to the clinic.
2. PARTICIPANT SCAN LOG. Send a copy of the written participant scan log covering participants scanned since the last data transfer. Use the log sheets to “flag” individual scans for review at the QA Center.
3. SCANS FOR REVIEW. Send original printouts of certification scans, “flagged” scans, random sample scans, and any scans requested for review by the QA Center. Please write directly on the printout the reason the scan was flagged, requested or being sent. These scans will be triaged visually based on the original printouts and analyzed on the Hologic workstation if necessary.
4. TRAVELING OPTICAL DISK. Send electronic copies of all scans acquired and reanalyzed since the last data transfer. Archive scans using the <COPY> feature. Do not archive the scans individually, as this will use up the disk space rapidly.
5. REANALYZED SCANS. Send original printouts of all scans that have been reanalyzed according to the QA Center instructions since the last data transfer. Attach the annotated printouts sent by the QA Center that indicated the problems requiring reanalysis. You MUST also send back the reanalyzed scan images on the traveling optical.
6. Copy of the Hologic Repair/Service/Upgrade Log (with a copy of the Hologic service report), if service has been done.

7. **DBARCHIVE. An archive of the participant database (dBarchive) will be sent at the end of each visit (ie. after the last randomized participant has been scanned at baseline or Year 5 followup).**

Please include the following on the disk label:

“MrOS DB ARCHIVE”

Batch #

Clinic name

Date of Archive

If more than 1 disk, label each disk as above and 1 of 3, 2 of 3, etc.

Diskette Label for DB Archive

<p>MrOS</p> <p style="text-align: center;">DB Archive</p> <p>Date _____</p> <p>Clinic _____</p> <p>Batch # _____</p> <p>Diskette No. ____ of ____</p>
--

Please note: The QA Center will use the most recent scan data for participants whenever there are multiple analyzed scans from the same date in the data base. Please notify us if there are exceptions to this.

Pack the materials carefully. The optical disk should be placed in a plastic bag and then wrapped in plastic bubble wrap to avoid damage. Batches containing the optical disk should be send via FedEx/UPS.

Assign a number to each batch of BMD data, beginning with the first batch of BMD materials sent. Start with batch number 001. The batch number should be the clinic identifier followed by this 3-digit number. Thus the batch number should be a 5-digit field: e.g. for the Portland clinic, batch number 1, the number should be PO001.

Complete a BMD Batch Checklist, indicating the number and which materials are included in the batch, and send it along with the batch materials.

The materials in the batch should be bundled separately by type.

Ship these items monthly to the following address:

Bonnie Blunt
MrOS Quality Assurance Center
UCSF Prevention Sciences
74 New Montgomery, Suite 600
San Francisco, CA 94105

5.4 Return Materials Sent by the MrOS Quality Assurance Center

The QA Center will return the following items to the clinical center after review:

1. Annotated printouts of flagged scans, random sample scans, and any other requested scans are returned to the clinical center with explicit instructions for reanalysis, as necessary. The clinic then reanalyzes the problem scans according to the QA Center's recommendations. The reanalyzed scan is then saved and re-archived and the database at the clinical center is automatically updated. An original printout of the reanalyzed scan is sent to the QA Center with the next data transfer to verify compliance.
2. Traveling optical.
3. Any recommendations for service, additional phantom scans, etc., as necessary based on the quality control data.

Appendix A. WHOLE BODY PHANTOM PROTOCOL

I. Phantom Assembly

Before lifting or transporting the phantom, break it down into its individual components. Use care, the impact force of a phantom component dropped from table height can cause severe injury, particularly if the impact is delivered through one of the phantom's beveled edges. Having another person help move the phantom components is strongly recommended.

A thin, gray PVC sheet is attached to the large white plastic piece that contains the two plastic locating pins. This HDPE/PVC combination is the bottom layer (base) of the phantom. Position it on the scanner table such that the PVC is on the bottom (i.e. the gray PVC is in contact with the table pad and the two plastic locating pins project out of the plane of the table towards the ceiling).

Place the second large white plastic piece on top of the phantom base, using the locating pins as a guide. The second piece should be placed such that the beveled edge forms a "V" with the base.

Next, place the medium size white plastic pieces on the phantom, again forming a "V" with the two beveled edges of the middle pieces. Then place the small white plastic pieces on top, forming another "V" with the small pieces. The final assembly will form a pyramid (see Figure 1, side view). This is the only valid configuration for the phantom measurement. All other configurations including adding materials to the phantom, removing pieces of the phantom, scanning the phantom upside down, etc. violate the intended use of the phantom and may produce invalid results.

II. Phantom Positioning

Carefully position the whole body phantom in the center of the scanner table with the head of the phantom at the head of the table. Allow 24" (61cm) of empty air space at the head of the table. Carefully position the phantom parallel with the long axis of the table, using the table pad markings as a guide. When properly centered, there will be a constant 3.5" (8.9 cm) gap between the side of the phantom and the front and back limits of the QDR 4500 scanner table (see Figure 1).

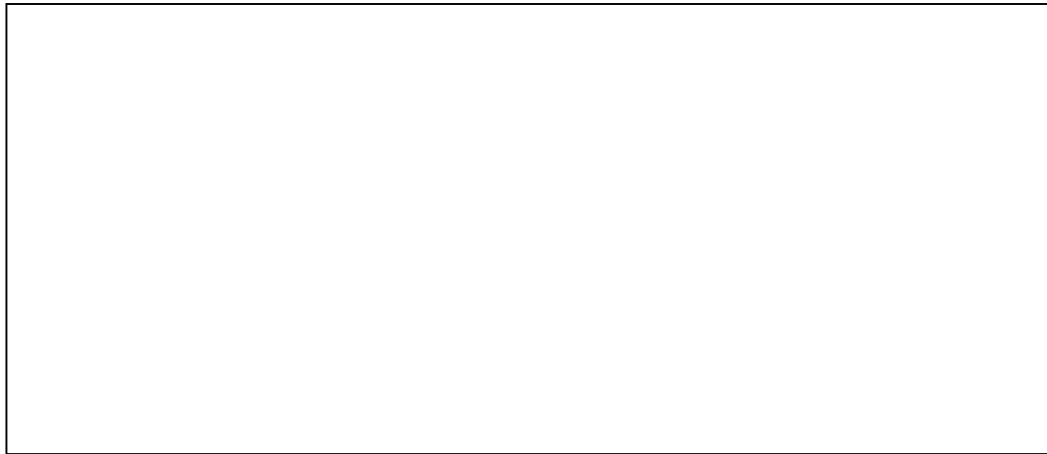


Figure 1. Layout of Whole Body Phantom positioned on the QDR 4500 scanner table. Also shown, the fully assembled phantom viewed from the side. (Note that the amount of empty space between the side of the phantom and the sides of the table will vary depending upon scanner model).

III. Data acquisition - Scanning the whole body phantom

1. Make sure that the phantom is centered, is parallel to the long axis of the table and is correctly oriented with respect to the head of the table.
2. Enter **Whole Body Phantom #xxxx** in the Name field of the Patient Biography (where **xxxx** is the phantom serial number, including any letters, found on the phantom label). Enter **#xxxx** in the Pat ID field of the Patient Biography (where **xxxx** is the phantom serial number, including any letters, found on the phantom label).
3. Remove all artifacts from the table surface. Extraneous objects in the scan field will interfere with the measured results in an unpredictable fashion.
4. Select the standard Adult Whole Body scan mode commonly employed at your facility. Accept the default scan length and scan width. Perform a complete scan of the entire table surface including the phantom. Do not interrupt the scanner during the measurement.
5. Carefully inspect the scan image to ensure that the phantom was (i) centered, (ii) parallel to the long axis of the scanner table and (iii) the phantom's head appears at the top of the image. If the scan image appears satisfactory, proceed to the analysis section. If not, carefully reposition the phantom according to the instructions in Section II and repeat the scan.
6. After receipt of the whole body phantom, scan the phantom four (4) times a day for the first week (20 scans). This will allow the setting of a consistent mean for monitoring performance and comparison purposes. Note that the whole body

phantom scans can NOT be added to the QC database. The QA Center will plot and check the data and notify the clinical centers of any problems.

7. After the first 20 scans are performed, scan the phantom three times a week.

IV. Analysis

A. General Comments

The goal of the analysis is to carefully delineate the various body regions in a standard and reproducible fashion, so that measured results will reflect instrument performance, not variations in analysis techniques. Of particular importance are the placement of the head ROI outline and the outlines that delineate the ribs, since these two regions affect global body composition and BMD. It is essential that the baseline measurement is technically adequate and that the analysis is performed by direct comparison to the sample analysis on the Hologic diskette labeled: "SAMPLE ANALYSES: WB PHANTOM" or "Whole Body Phantom Analysis Template". Use the sample scan for your model of scanner (see Table 1).

B. Specific Instructions - Hologic QDR systems

Follow the instructions in Sections II and III of Appendix A to acquire a technically adequate scan of the Whole Body phantom. Restore the appropriate scan from the Hologic diskette labeled "SAMPLE ANALYSES: WB PHANTOM" or "Whole Body Phantom Analysis Template" to the analysis workstation (see Table 1 for the correct scan to restore for your QDR model). Select the newly acquired WB Phantom scan. Then use the Compare feature to register the ROI outlines of the sample scan to the newly acquired scan of the WB Phantom. Once the ROI's have been matched as nearly as possible, complete the analysis and print the first and last pages of the report.

Archive the baseline measurement for safekeeping but do not delete it from the analysis workstation. All future whole body phantom measurements will be compared to the initial baseline measurement. After the initial measurement, the sample scan restored from the sample diskette should be deleted. Archive Whole Body Phantom scans to both the clinic and traveling opticals, then delete the scans from the hard drive.

QDR MODEL NUMBER	WB PHANTOM SCAN (RESTORE FROM SAMPLE DISK)
1000W, 1500, 2000 Pencil beam	1000/1500/2000 Pencil WB Phantom

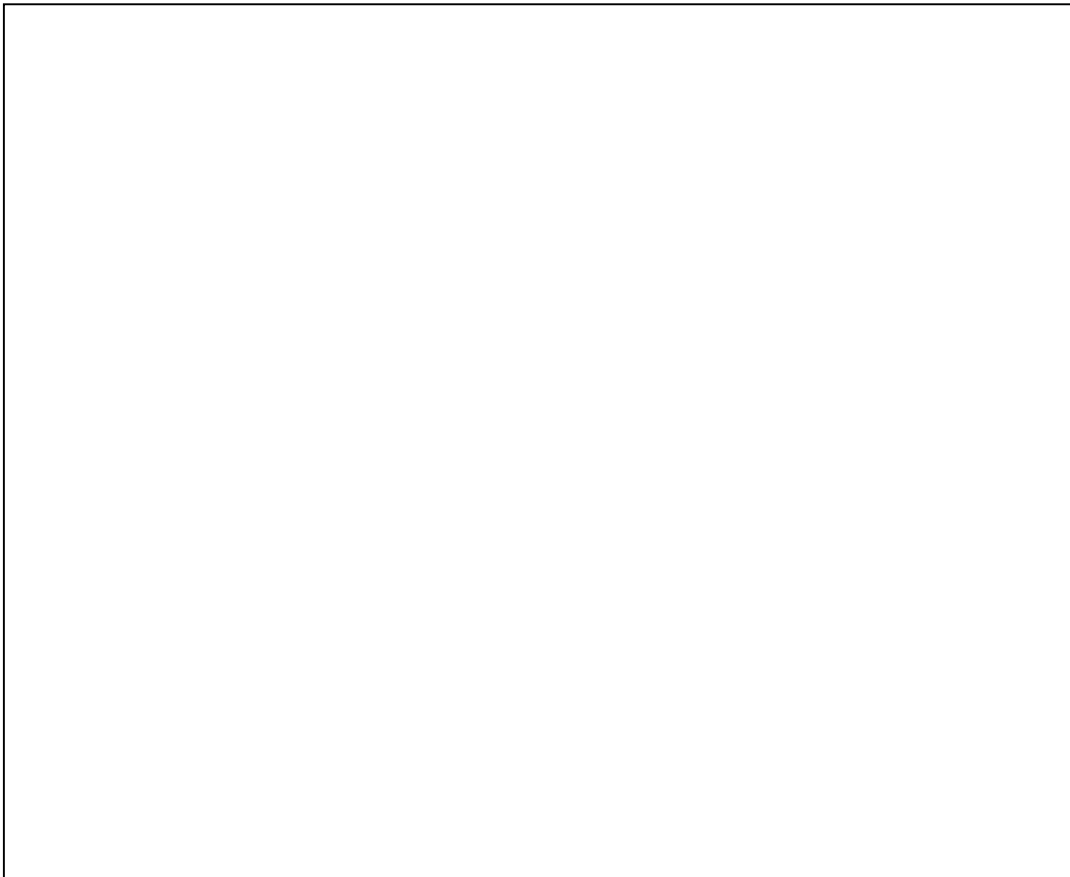
2000 Fan Beam	2000 Fan WB Phantom
4500W	4500W WB Phantom
4500A	4500A WB Phantom

Table 1. Scans to restore for a given QDR model number.

V. Interpretation of measured values

The phantom measurements should be printed out, placed in a logbook/file and kept at the clinic center. The QA Center will plot selected variables periodically from the scans sent on the traveling optical and notify the clinic center of any problems.

Please note a correction to the Biography in the following printout. The phantom serial number should be in the ID field: I.D.: #001



**APPENDIX B.
STUDY FORMS**

The following forms are included in this Appendix:

Batch Record Form

Bone Density Form (teleform)

Hologic Maintenance/Repair/Upgrade Log

Participant Scan Log

Master copies of the forms will be mailed directly to your clinical center.
Always keep a copy of any form you send to the QA Center.