

**BREAST DOSE SURVEYS IN
THE NHSBSP:
SOFTWARE AND
INSTRUCTION MANUAL
Version 2.9:**

**2D, Contrast enhanced and
DBT mammography**

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1. INTRODUCTION

Measuring the mean glandular dose to the standard breast¹ using a PMMA breast phantom has for many years been the main means of assessing the doses from mammographic systems. Although this is a valuable and simple approach to dose measurement it provides limited information on the doses received by individual women. As a result the periodic measurement of doses for samples of women undergoing mammographic examinations is also recommended.¹ This manual describes the use of Version 2.9 of a software programme that calculates and stores the results of such dose surveys. The latest version of the previously distributed software was known as Version 2.4. It is intended that the use of this software will help to standardise dose measurements and simplify procedures for national reviews of radiation doses in the NHS Breast Screening Programme.

2. DOSIMETRY PROTOCOL USED

The UK and European protocols for mammographic dosimetry use conversion factors that relate incident air kerma to the mean glandular dose (MGD) within the breast using conversion factors calculated by Dance and colleagues.^{2-4,6} More recently, the methodology has been extended for estimation of breast dose for digital tomosynthesis.^{5,7} To facilitate the calculation of MGD in patient surveys, typical breast glandularities are used for women in the age ranges 40-49 and 50-64 and for breasts in the thickness range 2-11 cm. The software provided with this publication facilitates the implementation of a breast dose survey using these procedures for, 2D digital mammography and contrast enhanced mammography and digital breast tomosynthesis.

2D PROJECTION MAMMOGRAPHY

In the IPEM, European and IAEA breast dosimetry protocols for 2D mammography the MEAN glandular dose (MGD) is estimated using

$$D = K g c s \quad (1)$$

where K is the incident air kerma (without backscatter) at the upper surface of the breast and g, c and s are conversion factors taken from the work of Dance² (1990) and Dance et al.³⁻⁶ Multiplication by the g -factor gives the AGD for a breast of glandularity of 50% and the c -factor corrects for the difference in breast composition from 50% glandularity.^{4,5} The values of g and c provided in the original publications and in the protocols are tabulated against half value layer (HVL) and compressed breast thickness. In the case of the c -factor data are provided for a series of breast glandularities and also for typical breast glandularities for women attending the United Kingdom Breast Screening Programme. The s -factor corrects for differences in dose at the same HVL and breast thickness due to the choice of X-ray spectrum.

DIGITAL BREAST TOMOSYNTHESIS

The formalism of equation (1) has been extended to digital breast tomosynthesis (DBT) using

$$D = K g c s T \quad (2)$$

where for DBT using a series of full field projections the tomo factor T for the complete exposure is calculated using:

$$T = \sum_i \alpha_i t_i \quad (3)$$

Here the t_i are the tomo factors for the individual tomo projections and the α_i are the weights of the individual projections. In this software the T -factor is taken from EUREF 2014 and values are provided for breast thicknesses from 20 to 110 mm for a wide range of tomosynthesis systems⁷.

3. NEW FEATURES IN THIS VERSION

3.1 Contrast enhanced mammography

The main change is the addition of the published g and c factors⁶ in the HVL range of the high energy exposures for contrast enhanced mammography. The option has been provided to perform higher energy calculations for systems with either a Copper or a Titanium filter. However, the user should be aware that the published g and c factors were derived from Monte Carlo simulations of a system with a copper filter. Using these factors to perform calculations for a titanium filter will therefore introduce additional uncertainties. Nevertheless the spectra are similar enough that these are likely to be small compared to other sources of uncertainty in the dose calculations.

3.2 Addition of T factors for more manufacturers

Only a limited subset of manufacturers could be selected for tomosynthesis calculations in version 2.4. This has now been extended to cover all of the main models in use in the NHSBSP. In addition, a bug limiting the calculation of 2D doses to a narrow subset of manufacturers has been corrected.

3.3 Update of g , c , s and T factors for dose calculations

The values used for the T factors were updated slightly from the previous version to better match published values. The resulting changes in calculated doses are expected to be less than 1%.

4. SURVEY METHODOLOGY

A breast dose survey involves the measurement of the mean glandular doses for a series of breast examinations (e.g. for 50 to 100 women) on a single mammographic system. For each exposure the X-ray factors are recorded (including target material, filter material, tube voltage and mAs). The radiographer determines the compressed breast thickness by reading the display on the X-ray set. The accuracy of the displayed thickness should be verified before starting the survey. This can simply be done by compressing a rigid material (e.g. Perspex) of known thickness to a typical force of 100N. If significant errors (>2mm) are encountered, correction factors should be applied or the unit re-calibrated.

From a knowledge of the output of the X-ray set for the tube voltage and target and filter material used, the mAs value may be used to estimate the entrance air kerma at the surface of the breast (K) and hence the mean glandular dose.

5. USING THE SOFTWARE TO CALCULATE DOSES IN A BREAST DOSE SURVEY

5.1 Introduction

The software provided comprises a Microsoft Access Database which uses a multi-page form for the entry and display of data for each survey as shown in Figure 1. The following sections discuss the use of each page of the form in turn. The first page of the form contains descriptive data for the mammography system. The second page of the form is used to enter the radiation characteristics of the X-ray set. Information on each clinical exposure is entered on the third page of the form. Subsequent pages display the calculated doses and summary data for the current survey. Sample data for a few dose surveys are included to illustrate how the software works. Once the user is familiar with the package this demonstration data should be deleted.

The screenshot shows the SURVHEAD - Microsoft Access application window. The ribbon includes 'Home', 'Create', 'External Data', and 'Database Tools'. The main form is titled 'X-ray set details' and has several tabs: 'X-ray set data', 'Exposure data', 'Calculated MGD', 'Graph of data', and 'Summary of analysis'. The 'X-ray set data' tab is active, showing a form with the following fields:

- Survey Number:
- Centre:
- Date of first exam:
- Date of last exam:
- Make of X-ray set:
- Model of X-ray set:
- Local ID of X-ray set:
- Type of installation:
- Tomo mode:
- Mode of kV selection:
- Standard kV selection:
- Routine/ age trial:
- Digital system?:

There is also a section for 'MGD to standard breast' with the following fields:

- Auto/manual kV:
- Auto/AEC setting:
- kV set:
- target:
- filter:
- PMMA thickness:
- MGD mAs:
- HVL:
- MGD:

At the bottom of the form, there are buttons for 'Refresh', 'Save Record', 'Print Summary Data Form', and 'Close Form'. A 'Navigation Pane' is visible on the left side of the window.

Figure 1: Multi-page form used for entering and reviewing dose survey data.

5.2 Mammography system details

It is useful to record all the characteristics of the mammography system used. However the only fields that are essential and used in the dose calculation are **survey number**, **make of X-ray set** and **tomo mode**.

Survey Number: The survey number is used to identify all the various sets of data from one survey and takes the form of an integer, which can be incremented each time a survey is added to the database. It is simplest if these are numbered sequentially from 1 upwards.

Make of X-ray set: The manufacturer is selected here from a drop down list. This information is used to select the appropriate T-factors in tomo mode and has no effect in 2D mode.

Tomo mode: If **2D mode** is selected the dose is calculated as in the previous version. If **tomo mode** is selected a T-factor is used in the dose calculation depending on the manufacturer of the X-ray system.

Routine/age trial: In previous versions of the software this field was used to determine which c-factors should be used for a whole survey. However in this version the c-factors for younger women are selected whenever the age field is less than 50. The field is retained to provide background information only, and for compatibility with earlier versions.

5.3 X-ray set data

Information on the physical characteristics of the X-ray set being surveyed are entered on the second page of the form as shown in Figure 2.

In order for the software to calculate entrance air kerma one needs to supply the following parameters for each kV/target/filter combination used clinically on the X-ray set being tested.

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- Survey Number:** This number must be the same as that entered above.
- kV:** Set kV and therefore an integer.
- Anode:** The anode material must be identified by the appropriate code **Mo** or **Rh** or **W**.
- Filter:** The filter material must be identified by the appropriate code **Mo**, **Rh**, **Al**, **Ag**, **Cu** or **Ti**.
- Output:** Output in μGy per mAs corrected to 1 metre from the focus of the X-ray tube on the usual measurement axis (i.e. one that passes through a point 4 cm from the chest wall edge). It is further assumed that attenuation by a compression paddle is not included. If you wish to use an output measurement through a compression plate this can be done if the transmission factor is set to 1.0.
- HVL:** This is the half value layer in mm of Aluminium measured as described in IPEM Report 59 and should include attenuation by the compression plate. It should be quoted to two significant figures.
- Distance:** This is the distance from the focus to the table top in mm.
- Transmission:** Measured fraction of air kerma transmitted through the compression plate. Set this to 1.00 if the output is measured through the compression paddle as is common practice.
- mA:** This field is optional and has been added to allow the calculation of exposure times. It should be completed for each kV, target filter combination used for which exposure times are to be calculated. It may also be left blank and has no effect on the dose calculations. (The mA can be determined from manufacturer's literature or exposure time measurements.)

Microsoft Access - [SURVHEAD]

File Edit View Insert Format Records Tools Window Help

X-ray set details X-ray set data Exposure data Calculated MGD Graph of data Summary of analysis

You need to enter a row of data for each combination of kV, anode and filter used
 Output: in microGray per mAs at 1 metre from focus
 Distance: from focus to table top in mm
 Transmission: measured fraction of air kerma transmitted through compression plate
 mA: Enter the mA only if you want to calculate exposure times

Survey No	kV	Anode	Filter	HVL	Output	Distance	transmission	mA
9 26	26	Mo	Mo	0.36	27.8	540	1.00	95
9 27	27	Mo	Mo	0.36	31.4	540	1.00	95
9 27	27	Mo	Rh	0.37	26.6	540	1.00	95
9 27	27	Rh	Rh	0.41	26.4	540	1.00	75
9 28	28	Mo	Mo	0.37	35.3	540	1.00	95
9 28	28	Mo	Rh	0.38	27.5	540	1.00	95
9 28	28	Rh	Rh	0.42	29.5	540	1.00	75
9 29	29	Mo	Mo	0.38	39.4	540	1.00	95
9 29	29	Mo	Rh	0.39	33.5	540	1.00	95
9 29	29	Rh	Rh	0.43	33.3	540	1.00	75
9 30	30	Mo	Mo	0.38	43.6	540	1.00	95
9 30	30	Mo	Rh	0.39	37.2	540	1.00	95
9 30	30	Rh	Rh	0.43	37.1	540	1.00	75
9 31	31	Mo	Mo	0.39	48.2	540	1.00	95
9 31	31	Mo	Rh	0.40	41.1	540	1.00	95
9 31	31	Rh	Rh	0.44	40.8	540	1.00	75

Refresh Save Record Print Summary Data Form Close Form

Record: 2 of 332

A number specific to that X-Ray Set.

Figure 2: Form for entering physical characteristics of X-ray set.

It is not necessary to directly measure all of these parameters as interpolation can easily be applied but all options must be included in the database. It may be convenient to assemble this data in a spreadsheet before “**paste appending**” it to the appropriate table in the database (i.e. X-ray set characteristics).

5.4 Exposure data

A record of the exposure factors for each mammogram is required. An example of such a dataset is shown in Table 2. The form on the database for entering this data is shown in Figure 3. The types of data requested, and how they should be entered into the database are discussed below. It is important that the data entered are in the right format. Where numerical values are requested do not enter the unit e.g. type in **28** rather than **28 kV**.

Survey Nu	Patient Number	View code	kV	Anode	Filter	Thickness	mAs	large cassette used	auto/man
9 319875	319875	LCC	28	Rh	Rh	70	91.0	no	A
9 319875	319875	LOB	30	Rh	Rh	75	75.0	no	A
9 329049	329049	LCC	28	Mo	Rh	56	80.0	no	A
9 329049	329049	LOB	28	Mo	Rh	60	77.0	no	A
9 329049	329049	RCC	28	Mo	Rh	55	79.0	no	A
9 329049	329049	ROB	30	Mo	Rh	58	88.0	no	A
9 330553	330553	RCC	27	Mo	Mo	39	38.0	no	A
9 330553	330553	ROB	28	Mo	Mo	45	46.0	no	A
9 337779	337779	LCC	28	Mo	Rh	45	65.0	no	A
9 337779	337779	LOB	28	Mo	Mo	38	49.0	no	A
9 340880	340880	RCC	28	Mo	Rh	51	63.0	no	A
9 340880	340880	ROB	28	Rh	Rh	54	68.0	no	A
9 340886	340886	RCC	28	Mo	Mo	41	41.0	no	A
9 340886	340886	ROB	28	Mo	Rh	46	54.0	no	A
9 340888	340888	LCC	28	Rh	Rh	49	59.0	no	A

Figure 3: Form for entering exposure data

Survey Number: Each exposure in the series must be identified with the same survey number provided in sections above.

ID Number: Each individual must be identified by a code, which is unique to this survey. This can be any combination of letters and numbers.

View code: Each exposure requires a view code that is unique to that patient. The codes for main images are as follows.

LCC for left cranio-caudal

RCC for right cranio-caudal

LOB for left mediolateral oblique

ROB for right mediolateral oblique

Where additional images have to be taken for the same views (e.g. if the breast was too big to fit on the first image) the following codes should be used.

LCC2 for a second image of the left cranio-caudal view

LCC3 for a second image of the left cranio-caudal view

and so on for the other views.

The software is designed for the two views used in screening i.e. mediolateral oblique (MLO) and cranio-caudal (CC). If some different views are used (e.g. a lateral) further codes may be used as follows.

LLAT for a left lateral view

RLAT for a right lateral view

Note however that the summary datasheet will only consider the standard views.

- kV:** Enter the set kV used - this should be an integer value. (Note that the use of a non-integer number will cause the dose calculation to fail.)
- Anode:** The anode material must be identified by the appropriate code **Mo** or **Rh** or **W**.
- Filter:** The filter material must be identified by the appropriate code **Mo**, **Rh**, **Al**, **Ag**, **Cu** or **Ti**.
- Thickness:** The compressed breast thickness should be entered as an integer number of mm. (Note that the use of a non-integer number will cause the dose calculation to fail.) Although most modern mammographic X-ray sets will display compressed breast thickness it is important to check the accuracy.
- mAs:** The post exposure mAs – for DBT exposures this should be the total mAs of all projections.
- Age:** Enter the age of the woman in years. This information is optional. However if it is entered it will determine the c-factor used in the dose calculation. If no age information is provided (as is usually the case) the software assumes all the women are aged 50 or over. Note that it is no longer sufficient to just enter “age trial” in the field “routine/age trial” as this has no effect on the dose calculation.

The following fields are not used in the dose calculation but are requested since they can provide useful feedback on examination practice. Some fields appear that are only relevant to film screen systems and can be ignored.

- Automatic mode:** Where a mammography system has different automatic modes please enter the one used here.
- Comment:** This field is available for the radiographer to enter any comments or explain any unusual aspects of the exposure.
- Error:** This is a **Yes/No** field with the default value **No**. If this field is changed to **Yes** this record of exposure data will not be used in the display and calculation of summary data. This could be done if the user suspects that the underlying data (e.g. mAs or breast thickness) is faulty. This may be apparent from an inspection of the graph of dose versus thickness. Where this occurs it is usually best to eliminate all the dose data for this patient (i.e. set **Yes** for each record). (Note: This field is not shown on the data entry form and can only be changed by altering the appropriate records in the table DOSEDATA.)

Table 1: Example of a set of exposure data

Survey Number	Patient Number	View code	kV	Anode	Filter	Thickness (mm)	mAs	large cassette used	Auto /man	Automatic mode	AEC density set	Age	Comment
1	AA10615	LCC	25	Mo	Mo	49	130		auto	CNT			
1	AA10615	RCC	25	Mo	Mo	42	101		auto	CNT			
1	AA1292	LCC	26	Mo	Rh	72	262		auto	CNT			
1	AA1292	RCC	26	Mo	Rh	78	318		auto	CNT			
1	AA14120	LCC	27	Mo	Rh	61	125		auto	STD			
1	AA14120	LOB	27	Mo	Rh	60	126		auto	STD			
1	AA14608	LOB	31	Rh	Rh	80	142		auto	STD			
1	AA14608	LOB2	27	Mo	Rh	72	168		auto	STD			
1	AA14608	ROB	28	Rh	Rh	80	161		auto	STD			
1	AA14608	ROB2	27	Rh	Rh	80	162		auto	STD			

5.5 Calculated mean glandular dose

The fourth page of the form displays the calculated MGD for each exposure as shown in Figure 4. This is the field labelled **dose**. If this field is blank some of the information necessary to calculate the dose is missing.

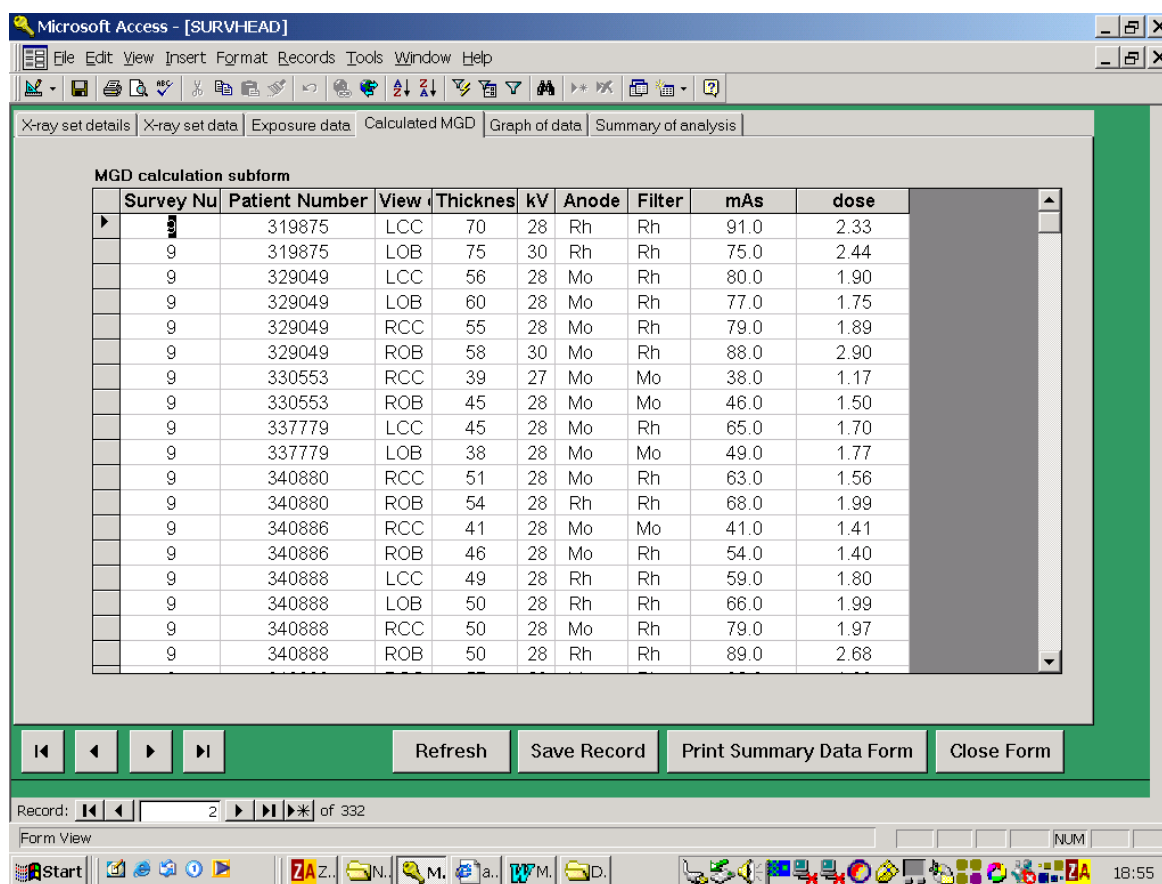


Figure 4: Form displaying calculated doses

5.6 Graph of data

The fifth page displays a graph of the MGD versus breast thickness for all the exposures in the current survey, as shown in Figure 5. Note that it may be necessary to press the Refresh Graph button to

update this graph. This graph may show some outliers caused by errors in the exposure data. A typical example is where the thickness is incorrectly recorded e.g. it is entered as 10 mm when it was really 100 mm. Any such outliers should be checked for the accuracy of the underlying data.

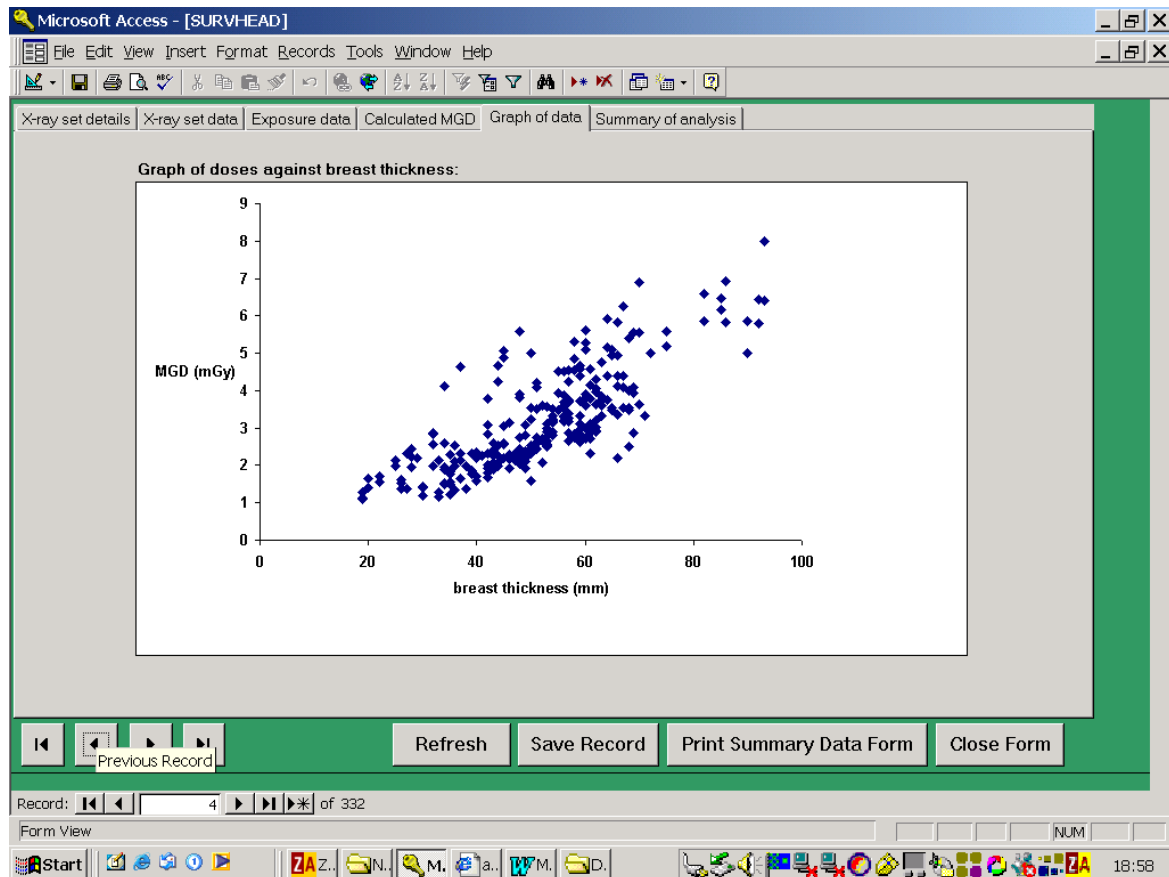


Figure 5: Form displaying graph of doses against thickness.

5.7 Summary of analysis

This page of the form (Figure 6) shows an analysis of the dose data in the current survey including number of oblique and CC images; average doses for main images for each type of view; number of images for each target/filter/kV combination. Note that a main image has a view code of LOB, ROB, LCC or RCC. View codes of LOB2, RCC3 etc are not classed as main images. The average doses for oblique views of breasts with a compressed breast thickness of 50 to 60mm are shown for comparison with the diagnostic reference level (DRL). The user may perform more detailed analysis by copying the data to a spreadsheet.

Survey Number: 11

Count of films

view	main films	Extra films
CC	144	
OB	130	

doses per main film

view	No of films	min MGD (mGy)	max MGD (mGy)	mean MGD (mGy)	mean Thickness (mm)
CC	144	1.08	6.24	3.05	50
OB	130	1.15	7.98	3.25	52

Average MGD for 50-60mm thick breasts

View	No of films	average MGD	2 s.e.m.	average thickness
OB	31	3.31	0.27	55

Anode	Filter	kV	films
Mo	Mo	26	36
Mo	Mo	27	65
Mo	Mo	28	56
Mo	Mo	29	5
Mo	Mo	30	7
Mo	Rh	27	61
Mo	Rh	28	2
Mo	Rh	29	19
Mo	Rh	30	8
Mo	Rh	31	12
Mo	Rh	32	3

Buttons: Refresh, Save Record, Print Summary Data Form, Close Form

Record: 4 of 332

Figure 6: Form displaying summary data

5.8 Printed report

Pressing the button “Print summary data form” prints a one-page summary of the data in the current survey. The printer used is the default printer set on the host computer. In addition to the data in section 3.7 this printout shows the average doses for one and two view examinations. The doses for an examination are calculated by summing the doses for all the images used in an examination and dividing by 2.

6. MAINTAINING THE DATABASE

The user has free access to all aspect of the database design. This will allow the user to trouble shoot any problems. However care should be taken not to corrupt features that are essential to the correct working of the database. The original version of the database software used is Microsoft Access 2007. Earlier versions of Access will not be able to run the database. In the event of difficulties contact the authors for help and software upgrades.

6.1 Backing up data

As with any other software package it is important to regularly back up your data. This can be achieved by making a backup copy of the database using the command **Tools/Database-Utilities/Compact Database** to both compress the database and save a copy using a different name.

6.2 Deleting dose surveys

When deleting a survey from the database (e.g. the sample data provided) it is necessary to delete all the records from the three main tables (*SURVHEAD*, *DOSEDATA* and *X-ray set characteristics*) with the appropriate survey number. The records from the *DOSEDATA* and *X-ray set characteristics* tables should be deleted before those in the *SURVHEAD* table. Any deleted survey numbers may then be reused for new surveys.

6.3 Incorporating survey data from previous version

It is likely that most users of the software have survey data in a previous version of the software that they wish to transfer into this new version. The appropriate way to do this is to select and copy all the records from each of the following three tables in turn. The records should then be **paste appended** to the corresponding tables in the new version of the software. Delete the demonstration data included with the software as described above.

- SURVHEAD
- X-ray set characteristics
- DOSEDATA

This will leave a few new fields added at the end of the new tables blank e.g. PMMA thickness, mA. These can be completed later if required.

7. REFERENCES

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