

Multi-Cultural Ergonomics Contextual Study in Designing a New Generation of Mammography Equipment



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ABSTRACT

In order to enhance the design of a new generation of mammographs, a comparative, contextual, and multi-national study was conducted in several countries. Operators and surgeons, work environments and equipment usages were analyzed and compared to provide operational recommendations for design improvement. This presentation will present the methodology used and will share some results.

Keywords

Ergonomics Assistance, Ergonomics Design, Mammography,

INTRODUCTION

Our mission consists in assisting the design team by ergonomic expertise in order to establish recommendations that the team can directly apply in the design, to counsel the team all through the conception phase and to validate the final design at project stage, the prototype and the final product.

The first part of the mission consisted in performing the ergonomic study of mammographic activities in different countries. The aim of this study was an evaluation of the workload based on direct observations of work, on operators' and radiologists' interviews and on measures effected on observed workstations. It resulted in a precise diagnosis of operators' work, which allows to reveal the weak points of the extant GE machine and the interesting points of the rival machines. From this report, recommendations are established according to European and ISO norms. As far as we know, the ergonomic ISO norms are in conformity with the requirements of most countries.

Three categories of mammographic activities were observed: the preventive one –

screening – and two clinical activities – diagnostic and surgical (biopsy).

The screening activity consists in performing the standardized examination (4 exposures) on patients who constitute the risk group (for example women over 50). The aim is to detect breast cancer as early as possible. This activity mainly requires productive performance, because the number of patients can be very important (80 per day).

The clinical diagnostic activity consists in performing the mammographic examination, which can be standardized or not. In many cases this examination can require more than 4 exposures. This examination is prescribed by a doctor following his or her medical suspicion. This activity mainly requires high precision because of the responsibility of diagnosis.

The clinical surgical activity consists in performing the biopsy on the radio control. Commonly the stereotaxy devices are used to optimize the precision of the biopsy. This activity is composed of two parts – radiographic activity consisting in placing the breast and positioning the biopsy needle, and the surgical one consisting of the biopsy itself. Both are coordinated and performed under radiological control realized by the mammograph.

Two types of machines are used: the classic mammograph with the up-right stereotaxy device and the prone table machine. This activity mainly requires very high precision and good accessibility for the surgeon.

The ergonomic study was carried out in Sweden, in the USA and in Japan. In Sweden only the screening activity was observed. In the USA we could observe one screening examination and one biopsy (without the possibility of video recording). In Japan we could observe only clinical diagnostic examinations, without the possibility of video recording, and simulations of clinical examinations on volunteers who could be recorded on video.

METHOD

The interviews with the operators were recorded. Borg's scale was used as a subjective evaluation of the workload in Sweden. In Japan a special questionnaire was elaborated and used.

The operators' activities were observed. This observation was continuous in Sweden and punctual in the USA and Japan for organizational reasons. The operators' mammography tasks were recorded on video. All observed activities were recorded in Sweden, only one examination in the USA, and only simulations of the real activities in Japan.

Data were collected with the following methods:

- direct work observation with video recording (Sweden, USA)
- direct work observation without video recording (USA, Japan)
- work simulation with volunteers (Japan)
- operators' interviews

The heart rate of two operators was recorded with a heart rate monitor BHL6000 Bauman&Haldi during two periods of activity with the GE DMR machine in Sweden.

Biomechanical analysis was realized by the BIOVECT method from images obtained with video recording.

RESULTS

On the three types of mammographic activities the main tasks were identified. The most important attention was paid to the standard mammographic examination comprising 4 exposures (two vertical and two oblique), performed as a screening examination or, in about 50% of cases, as a clinical diagnostic examination. The different operating modes were described. We dissociated the tasks directly depending on the machine including the technical procedure of mammography and the tasks depending on work organization including the patient's reception and the treatment of cassettes. Only the former were analyzed in detail in this study.

A biomechanical vector analysis of posture was performed in order to reveal the postural discomfort generated by the machine.

Apart from the GE, the other observed machines were: Siemens Mammomat 3000, LORAD M-IV from Delta Medical System Inc., LORAD Mammotome prone table, Mammovision from Ficher Imaging, Toshiba Mammorex 100A.

Special attention was paid to the use of signals and command devices on each machine in each type of activity.

The operators interviewed in all the hospitals, working on the different machines had comparable levels of experience and skill.

Task identification and operating modes on Standard examination activity

The tasks depending on the machine were observed from video recording. The sub-tasks are as follows:

- adjusting the height of the bucky
- placing the breast and compression
- exposure
- changing the cassette

These tasks were quite the same in all visited hospitals in the three countries. The differences of operating modes concerned essentially the postural adaptation observed only in Japan for the adjusting of oblique exposure.

For the oblique exposures the applied angles vary from 50 to 90°. In most hospitals these angles are close to 65°, but in some Japanese hospitals there are more variations. From the ergonomic point of view, those differences are insignificant; they depend on the differences of medical demand.

The applied compression forces vary from 4 to 20 daN. However in most cases and regardless of the country, this force is close to 8 daN. The radiologists who were asked about the quality of radios realized with that force, considered that this quality is satisfactory. Our observations and even interviews with the radiographers are too few to allow generalization, but it seems that this compression force is applied regardless of the breast dimension and depends essentially on the radiographer's preference.

The average time of a standard examination is comparable in the three countries. It is slightly longer in the USA where the patient's comfort is considered as a priority. This time is about 6 min and varies from 4 to 9 min.

It could be impossible to perform a precise comparison between the examination times performed with the different machines, but it seems that these differences are not very significant from the ergonomic point of view. The differences due to the machines are important for the radiographers' comfort and not for the patients' comfort.

Vector biomechanical analysis of postures

Some working postures were chosen for analysis from the video recording of operators' activity. They were analyzed with the software BIOVECT to determine the angular

positions of limb segments and the articular biomechanical constraints, especially on the spine.

Two main types of postures were observed during mammographic activity. The first one, which could be called "classic", was observed in Sweden, in the USA and in Japan when the mammography was performed by women.

The global analysis of these postures shows that the totality of the spine is strongly solicited in lateral inclination. This is due to the size of the RX head which forces the operator to avoid it by moving laterally and vertically. This movement can only be performed by moving the trunk if the operator wants to remain close to the patient.

The second reason of discomfort is the distance between the bucky and the RX head which does not permit to place the patient's head in this area. Consequently the operator has to shift even further aside to allow for the patient's head.

This solicitation is incompatible with repeated practice and engenders, in the long run, articular and muscular pain and complaints corresponding to musculo-skeletal disorders.

The working space limited by the size of the RX head and the short distance between the bucky and the XR head often forces the subject to place the skeleton of the lower limbs in biomechanical strain positions, especially at knee level.

The second type of working postures was observed only in Japan, essentially with the male operators having a long experience in mammography. They work to adjust the oblique exposures in a kneeling position with the arms over the shoulders and often with twisted trunk. The results of analysis show that these postures are very uncomfortable for the lower and upper limbs, but less uncomfortable for the trunk.

It seems that it is not useful to adapt the commands and the display of machine for that kind of procedure, because of their cultural character. Yet, the machine conception should be optimized to avoid the postures used in the "classic" procedure.

From the ergonomic point of view it should be interesting to minimize the size of the RX head and to maximize the distance between the bucky and the RX head

CONCLUSION

The operating mode of mammography screening is quite the same in all visited hospitals. This mode varies in Japan, when the mammography is performed by male radiographers with a long experience. They adopt a postural operating mode using kneeling or squatting postures, probably for cultural reasons. It is interesting to note that in Japan the female radiographers present the same operating mode as in Sweden or in the USA.

Some differences concern the time pressure due to the time allocated for each patient. This time is much more important in the USA than in Sweden or in Japan because of the big impact on the patient's comfort.

The postural strain provoked by the machine is quite similar in all observed machines. It depends on the width of the RX head and on the distance between the bucky and the RX head. The main differences concern the commands more or less easy to use.

The observation of prone tables shows very interesting ergonomic advantages from the patient's and the operator's points of view. The patient's horizontal position deserves a deep reflection for the new mammograph.

RECOMMENDATIONS FOR THE NEW MACHINE

The use of the machine, even when very intense, does not engender risks of apparition

of musculo-skeletal disorders, although the postural load is not slight.

The main recommendations to the conception of a new machine concern the general conditions of use, the commands and the display.

Patient's comfort

From the patient's point of view, the main complaint that is repeated in all countries is the breast pain during compression. The way to diminish that problem could be the new conception of the bucky and of the paddle.

The bucky should have more rounded corners. The form of the bucky should be redesigned in a shape adapted to the ribcage. Above all, the corners are considered very uncomfortable by the patients.

The coating of bucky should be non-slippery and should be realized with a material that gives the impression of a warm surface, or should simply be warmed up. Many patients complain about the "cold bucky".

The paddle could be adapted to the breast form. To optimize the form of the paddle, a study about breast pain would be very useful.

Operator's comfort

The notion of the operator's comfort includes the efficiency and the performance of the man-machine system. The recommendations concern the general use of the machine: its dimensions, its mobility and its polyvalence, and particularly the commands and the signals.

Dimensions

We could not find the precise location of the sub-mammary furrow, but from indirect calculation it is on average at 1100 mm from the ground for an average woman of 1640 mm. If we consider the 99 percentile of American woman at 1830 mm, the sub-mammary furrow should be between 1300 and 1350 mm. During oblique exposure at 90° the axis of the bucky should be 150 mm higher than the sub-mammary furrow. Therefore the maximal height of the bucky should reach 1500 mm. Additionally, the observation of Japanese conditions shows that the height adjustment of bucky at 650 mm from the ground would be satisfactory. Thus, the regulation of the height of the bucky should start from 650 mm and go up to 1500 mm. Those dimensions include 99% of world population, both in a standing and in a sitting position.

The study confirms the necessity to provide a bigger distance between the RX head and the bucky in order to allow more room for the operator's head and neck posture. The current distance in the GE DMR is 450 mm; it should be increased by at least 50 mm and preferably by 100 mm.

The width of the RX head should be reduced in order to clear the room for the operator's head. The current width is 250 mm; it should be reduced by at least 20 mm and preferably by 60 mm.

Mobility

It seems that the decision to design the RX head with a rotation axis on the bucky should be very satisfactory for the working postures, because it would facilitate the adjustment of the breast in oblique positions.

The decision to mechanize the up and down movements and rotation movements seems to be very satisfactory. A very interesting improvement should be the

programmed movements of RX head, which could be operated from the command panel placed in the satellite, as in Toshiba Mammorex. The study suggests that more than 50% of all mammographic examinations are standard and composed of 4 standard exposures.

Commands

From the results of our study, we can distinguish two kinds of commands. The first kind concerns commands commonly used in all procedure of mammography. They are RX head up and down movement, RX head rotation, moving paddle to compress and decompress and cassette removal.

The second kind concerns the commands which are not used systematically, or only in particular procedure (magnification, stereotaxy). The two groups of commands should not be confused. They should be clearly distinct even for a novice operator.

In the first group the commands of up and down movement and of rotation could be grouped in the same block of buttons. If this is the case, the buttons for up and down movement and for rotation commands should be chosen so that the direction of the button correspond to the direction of the RX head movement it commands.

This block of buttons should be placed in a zone of comfortable reach. The difficulty to find an acceptable location for these manual commands comes from the mobility of the RX head and of the bucky. The extreme vertical positions of the bucky range from 650 to 1500 mm from the ground and the extreme horizontal position of the RX head is between $+90^\circ$ to -90° , that is from +920 mm to -920 mm. It is therefore impossible to place all the manual commands comfortably on the head and on the bucky. A radical solution could be the vocal command or the remote control. If that solution is impossible it should be envisaged to design a satellite attached to the immobile part of the machine. This satellite could provide a convenient location for the commands of the programmed movements of the RX head.

If the block of commands is placed on the bucky or/and on the RX head it should be repeated on both sides and preferably both on the bucky and RX head. Only such a solution allows the operator to have the commands always comfortably available in any head and bucky position.

The block of commands placed on the bucky should be clearly differentiated from the rest of the bucky to avoid mishandling by the patient. The commands should be indicated by the color and texture coding. This type of coding facilitates the orientation for the operator.

The command which moves the paddle for breast compression cannot be used manually because the operators use both hands to place the patient in the right position. A pedal should be used instead, and it should be easily available without visual control. In that case, the best solution would be the vocal command. If that is impossible, the pedals should be duplicated and easily mobile. The pedals on both sides of the machine should have symmetrical functions (as it is the case in actual DMR machine). They should be easier to locate and to push.

Signals

Concerning the display it is necessary to find better location for information panel display. It seems that the best compromise would be the display in the lower part of the column at about 200 mm from the ground. The angle of inclination of that display should be about 30° .

The dimension of the characters on the display should be legible at a distance of about 2 m. For this distance the optimal dimensions are between 12 and 13 mm of height. If luminous characters are used, the contrast of illuminance should be 1 : 10. The illuminance of the character should be no less than 35 cd/m².

VALIDATION OF THE FIRST MODEL

The model in scale 1 : 1 was presented for 2 operators having a long experience in mammography with existing machines. The location of the commands and display was tested. The operators were asked to choose the most comfortable location for them.

The global analysis of the postures showed that the totality of the spine is less strongly solicited in lateral inclination than with the DMR machine. The location of the commands on upper part of the RX head provokes postures with excessive arm extension.

VALIDATION OF THE PROTOTYPE

The prototype was presented to 10 operators, having a long experience in mammography with existing machines, were asked to try to manipulate the prototype with two subjects. The operators' height varied between 150 and 185 cm and their weight between 50 and 90 kg. They were quite representative of a general population of operators, from the morphological point of view.

The prototype presents interesting advantages due to the dimensions of the RX head and the rotation axis in the bucky. These advantages are confirmed by the operators from European countries and from the USA. The working postures generated by the machine are freer than in the ancient model and the motorization of the column movement is appreciated. It seems to be very helpful for the operators to include in the training program elements of postural economy, which allow them to benefit much better from the ergonomic layout on the machine.

The speed of the column movement is differently appreciated by European and American operators. The former prefer the faster speeds, the latter the slower ones. From the ergonomic point of view the tested speeds range all within acceptable limits. So why any detailed study about the speeds be needed. The definitive choice should be based on technical arguments. It may be interesting for the customer to choose through software two programmed speeds among four available. The range of speeds currently proposed seems to come up to the expectations of the different operators.

The commands of the column movements should be doubled and placed in the lower part of the RX head and the proximal part of the basis of the bucky.

In the prototype the bucky and the paddle have remained the same as in the ancient model. It is a pity, especially for the form of the bucky, because the current form provokes the patient's discomfort, which could be diminished with a new design. The technical solution for the paddle movement with the rails on the lateral parts of the column seems to be less compatible with the security and comfort of the patients' hands in the MLO exposures.

The pedals with the command of the compression paddle movement have not changed, so it is difficult to estimate the impact of the definitive pedals. The extant ones do not seem very comfortable to use. A new design of pedals would be welcome.

The new pedals should be lighter, easy to move and easy to activate. They are activated without visual control and in an uncomfortable posture. This is why a "mushroom" like pedal should be recommended reacting to any pushing action in any place on the pedal.

Two solutions could be accepted. The first one is to propose two pedals: "compression down" and "compression up", fixed on the same support. The second one is to propose the bi-directional pedal commanding up-and-down movements of paddle compression. Two supports would be necessary - on both sides of the column, easily

accessible for the operator's food.

The first solution is easier to master, but slightly less comfortable to use. The second one needs a longer and harder apprenticeship, but once mastered it is more comfortable..

REFERENCES

MONOD H., KAPITANIAK B 1999m Ergonomie. Masson, 1999, Paris.

NOWAK E. 2000, The anthropometric atlas of the Polish population; data for design, 2000, Institut of Industrial Design, Warsaw, 1 vol. 27 p. 18 tables

AFNOR, 2005, Recueil des normes ergonomiques (2005) L'Association Française de Normalisation (AFNOR), France

PENINOU G., KAPITANIAK B. Biovect, 2006, A Vector Analysis Method on Photographic Documents Applied to Ergonomic Analysis, in International Encyclopedia of Ergonomics and Human Factors 2nd ed., 2006, Francis&Taylor, 1942-1948