Data corruption

Data corruption is the term used by computer personnel to explain how and why a computer sporadically produces incorrect or unreadable data. It is not just the concern of these experts, however: it should concern everybody from the person whose name unexpectedly appears on a bad debt register to the general practitioner with his surgery computer. The main causes of data corruption are defects in the hardware (for example, in the integrated circuit chips) and problems concerning the user and the software—the programs.

Three parts of the computer hardware may cause data corruption: the integrated circuits, the magnetic storage media (tapes or discs), and power supplies.

Modern integrated circuits are very reliable and have lifetimes of more than 10 years, but they are easily damaged by inappropriate handling. In practice defects in the circuits are rarely a problem; much more frequently data corruption results from damage to the storage media. For example, a microscopic speck of grit may damage the surface of a disc and erase information or make it unreadable. A minute scratch has a large effect because it disorganises the data sequence. All large computer installations filter and humidify incoming air—and staff working in the computer area should be forbidden to smoke.

Any part of the computer system may malfunction if the power supply unit does not remove transient high voltages in the mains. Ideally a power unit should also contain an auxiliary battery so that if the mains fails there is enough power for the computer to close down its operation in an orderly way.

Vandals may gain access to the computer by a telephone line or by using an unguarded keyboard. Computer vandals usually have considerable skill and may find a route to the deepest software recesses of the computer and there cause extensive corruption.

An inexperienced computer user may accidentally enter data

that are not displayed on the screen but which form characters in the memory. These are then transmitted to the storage media and stay there until they cause trouble later on. Well designed software should trap such characters and notify the user. Unfortunately, inexperienced users have a knack of doing the most unexpected things and somehow even the best traps may fail.

Nevertheless, the main source of data corruption is poorly designed software. Given that information is typed into the computer correctly, a program should check the entry, where it is to be put, and how it is to be arranged and used. The problem is that when a software program has many options it may be impossible for the designer to test them all. For example, in a program where information from the user causes the flow to branch five times there are 32 possible paths to completion. In a larger program (such as that used by a general practitioner to store data on patients) the number of possible paths is enormous, and few software firms could guarantee to have checked all the permutations.

What, then, can be done to prevent data corruption and to cure it once present? To deal with the hardware first, the preventive approach is based on providing the computer with an optimum environment and a protected mains supply with auxiliary battery facilities. At the least a "No Smoking" room should be set aside for the computer, where all its media and supplies can be stored securely.

Data corruption caused by software can be prevented only by good design. For this reason anyone buying software should talk to unbiased users to see if they have had any problems with the proposed software. The conservative approach is to buy software that has been available for a year or two—since all its errors are likely to have been detected and corrected.

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Regular Review

Mammography and screening for breast cancer

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Almost 30 years ago Gershon-Cohen and his coworkers were the first to suggest that mass x ray surveys might be used in the early detection of breast cancer and showed that serial mammography at six month intervals could detect small, presumably early, breast cancers.^{1,2} They found a lower incidence of metastatic spread to the lymph nodes in patients whose cancer was first discovered in this way.

The principal impetus for the development of screening for breast cancer came from the Hospital Insurance Plan study in New York inaugurated in 1963.³ This randomised

controlled trial, using mammography and palpation, was the first to show a reduction in mortality (which has been maintained at 30% over a period of 10 to 14 years⁴). The early results of the New York study, published in 1973, stimulated further studies designed to answer the operational questions which would follow the introduction of breast cancer screening, and the American breast cancer demonstration (BCDD) project⁵ and the west London screening programme⁶ convincingly showed that mammography had a higher specificity and sensitivity than did clinical examination.

Parallel to these epidemiological studies advances were being made in mammographic techniques and apparatus, and the minor x ray changes associated with minimal breast cancers were being clarified. In the late 1960s Gros pioneered dedicated mammographic units with compression of the breast and introduced molybdenum anodes—advances which improved the mammographic image. A vacuum packed film/screen system was first described in 1969, and this led to a dramatic reduction in the (hitherto high) radiation doses used.⁷ Considerable credit must go to Lundgren, who refined the single oblique view of the breast and had the courage to use it as the only screening modality in the pilot study which preceded the present Swedish randomised controlled screening studies.^{8,9}

More recent advances—the use of K edge filtration, grids, and magnification techniques—have further improved the image obtained. It is against this background of continuing advances in mammography and cooperation between epidemiologists and radiologists that the present screening programmes should be considered.

The introduction of breast screening has been delayed in Britain on the grounds that many problems remain unsolved. The most important questions have now been answered and some others are likely to be during the next few years. The time is rapidly approaching when decisions must be made on the introduction of screening or early detection programmes in Britain. The Minister of Health has set up a committee of experts to review the matter.

Some of the answered questions

Is screening for breast cancer beneficial? The answer to this question is an unequivocal yes. Randomised controlled trials in New York^{3,4} and Sweden^{10,11} have shown reductions in mortality from breast cancer of between 30% and 40% achieved by screening. The design of these randomised controlled trials has avoided the problems of lead time bias, length time bias, and selection bias.

Two recent non-randomised but well conducted case-control trials in Holland support these results.^{12,13} Reports from other trials, including the massive American BCDD project with 280 000 women in whom 3550 cancers were detected,⁵ and the British geographic comparative study, from which only incomplete results are yet available,¹⁴⁻¹⁶ also support the concept of a benefit derived from screening. They show a reduction at detection in the size of the tumour and spread to the axillary nodes—factors which are associated with a favourable prognosis.^{17,18}

Sceptics have argued that no “cure” can be claimed until the follow up has been continued for 30-40 years from detection.¹⁹ In practice the probability that screening by mammography does reduce mortality is so high that it could be considered unethical—and it is certainly unfair—to deny women this chance for the next 30 to 40 years until an academic point has been proved. Even a nihilist must accept that a 30-40% reduction in the chances of dying from breast cancer within 10 years from detection is something worth offering to women. There is now no reasonable doubt whatsoever that women who are included in screening or early detection programmes have a lower mortality from breast cancer than those who are not.

Furthermore, the benefits resulting from the early detection of breast cancer are not just limited to reductions in mortality. A reduction in the size of tumour at presentation

may allow more conservative forms of treatment and easier local control of the cancer^{15,20} and may even reduce the need for radiotherapy.

What are the relative places of mammography, clinical examination, and self examination? This is the question addressed by the British trial of early detection, and its results should provide a complete answer. A few pointers are already available. Mammography in the early 1960s (Hospital Insurance Plan study) was inefficient compared with clinical examination: for every cancer detected by mammography three were discovered on clinical examination. By the 1970s (breast cancer demonstration study) for every cancer detected clinically, six were identified on mammography—an 18-fold increase in the mammographic detection rate from improvements in technique and interpretation.²¹ In the Dutch project if mammography alone had been used the sensitivity would have been 95% and the specificity 99%, whereas clinical examination alone would have yielded 41% and 97% respectively.²²

These major studies all indicate that modern mammography is much superior to clinical examination in detecting cancers in situ and those less than 2 cm in diameter.^{5,10,12,13} In screening terms it is also less costly per case detected.^{22,23} The conclusion seems to be that in future screening programmes clinical examination should be reserved for any symptomatic patients who may present and for patients in whom screening detects abnormalities.

Initial reports from the Nottingham breast self examination study indicate favourable results in terms of the characteristics of the tumour—namely, an increase in the numbers of patients with tumours less than 2 cm in diameter from 30% to 57% and a reduction in those with spread to the axillary nodes from 52% to 35%.¹⁵ These shifts to cancer detection at an earlier stage are comparable with the findings of the Hospital Insurance Plan study, which ultimately proved to have a reduction in mortality of 30%. Four American breast self examination studies have found broadly similar results.²⁴⁻²⁷ Nevertheless, if breast self examination is to be beneficial it must be practised regularly and proficiently.²⁸ At present breast self examination may be regarded as a useful supplement to a modern screening programme based on mammography, but it should not be seen as a substitute.

Is mammography safe? Whether low doses of radiation cause breast cancer is unknown, but if so, the incidence is so low that it has never been observed.²⁹ An increased incidence of breast cancer has been reported after high doses of irradiation: examples are atom bomb survivors and patients undergoing radiotherapy or repeated chest fluoroscopy.³⁰ High doses have most effect on women aged under 20 but the risk is more than halved by the age of 30. No risk has been identified in individuals over 20 who have been exposed to less than 100 rads.³¹ No excess of cancers has been identified in individuals at any age exposed to a skin dose of less than 17 rads.

The “minuscule doses” administered during modern mammography should be seen in context.³² At the time of the Hospital Insurance Plan study mammography doses were in the region of 2 to 3 rads, whereas with modern mammography doses in the range of 0.05 to 0.3 rad per exposure are commonplace—indeed, higher doses are unacceptable.

The American College of Radiologists (in a climate of high anxiety) has recommended that: “For asymptomatic women the first or baseline mammographic examination should be performed between the ages of 35 and 40. Subsequent mammographic examinations should be performed at one to three yearly intervals. After age 50 annual or other regular

interval examinations should be performed.”³³ This is now accepted as a standard of good practice.

Certainly all ionising radiation carries a risk. With the very low doses achieved by modern apparatus, however, properly filtered,^{34 35} and with high speed film screen combinations,^{7 36} the potential hazard of inducing breast cancer is negligible.

Some unanswered questions

The main questions on breast screening have now been answered but more data are needed before a full breast screening programme is introduced on a service basis. Indeed, all existing and future screening programmes should be carefully controlled and designed to produce data that will contribute towards the scientific evidence which can be used in cancer control.

One major controlled Canadian trial is designed to compare the results of screening younger and older women, to identify combinations of risk factors, to provide cost effectiveness data, and to give information on the clinical course of cancer.³⁷ The British detection study will provide valuable data on methods, including cost effectiveness and an estimate of the benefits of screening in the United Kingdom.¹⁴

At what age should screening start? In the initial analysis of the Hospital Insurance Plan data all the reduction in mortality occurred in women over the age of 50, and no difference was found between the study and control groups in deaths at ages 40 to 49. These analyses were, however, on the basis of age at death. Since women were allocated to groups according to age at entry the study design required analysis on this basis. When that was done a benefit from screening was observed in the younger age group,³⁸ but with a lag period of five to seven years from the date of screening before the maximum benefit to the younger age group became apparent.

The Swedish study report showed a similar lack of early benefit in the younger age group. Nevertheless, the number of stage II or more advanced cancers at detection was reduced in both the younger and older age groups, accompanied by an excess of in situ and stage I cancers in the study groups compared with controls. The breast cancer demonstration project also identified the same proportion of early cancers in the younger women as in the older.⁵

These results suggest that those cancers detected early in the younger age groups would otherwise have presented and caused death later—in the age range accepted as that at which the incidence of breast cancer is maximal. Might this imply that detection in the young may prevent mortality in the old?

What is the ideal screening interval? Information is still lacking on the effectiveness of modern screening techniques using a shorter interval than the two to three years of the Swedish trial. Groups of women may be identified who are at high risk of developing cancer, but more data are required before screening is limited to these individuals. Possibly, however, the high risk groups may need to be screened with a shorter interval than the remainder of the population.

What are the costs of screening? Any screening programme should be organised in the most cost effective manner. A balance sheet must be considered in which the expenditure on the programme together with detrimental effects on the population are weighed against financial savings and benefits.

Various estimates of costs have been made varying from \$12 per patient screened and \$2000 per detected cancer when single view mammography alone is used⁹ to £16·50 per screen and £6000 per cancer detected using clinical examination,

two view mammography, and usually thermography.³⁹ The highest estimates are of \$195 000 per cancer detected⁴⁰ and £80 000 per life saved.⁴¹ The estimates for the continuing Canadian trial are \$25 per patient screened by mammography and clinical examination.³⁸ The current estimate for mammographic screening in Britain is £10 per patient, with the cost of detecting each cancer less than 2 cm being under £4000.

The *Lancet* proposal³²—screening at a breast clinic jointly staffed by surgeons, radiologists, histopathologists, and cytologists—has been estimated to cost £80 for each initial attendance (J L Price, personal communication)—£60m for 750 000 attendances. For the same sum a series of dedicated screening clinics could screen 6 million women at £10 per head—the total population of women between 45 and 70 in Britain (J L Price, personal communication). The costs of patients referred for biopsies which prove to give benign findings must be added to these basic costs, but in a high quality unit these should be fewer than two for each cancer detected.

The deleterious effects on the population of unnecessary (benign) biopsies are obvious, but there are also psychological and psychiatric problems associated with screening programmes. Not only may the level of cancerophobia and anxiety in the population be raised,^{19 42} but women who have symptomless breast cancer detected by screening may adapt less well to their illness.⁴³ The use of nurse counselling, however, is proving valuable in diminishing these problems.⁴⁴ On the credit side are the savings in the treatment of advanced cancer avoided by early cure together with lower costs of less extensive initial surgery.

The basic costs of a screening service should be seen in context. When the costs were compared with those of screening for cervical cancer in Sweden the breast:cervix cost ratio was 51:58 per patient screened and in terms of detected cancers it was 9100:14 000.⁸ Another measure is the cost to the NHS in Britain of £50 a year for each woman on the contraceptive pill.

Some answers to other questions

What are the dangers of screening? The real dangers of screening all derive from the quality of the screening process. The techniques, both technical and clinical, must have a high sensitivity and be capable of detecting a high proportion of in situ and very small invasive cancers. The specificity of the programme must be the highest possible. This can be achieved at the price of a high biopsy rate⁴⁵ or by adopting a secondary intensive investigation policy, using magnification, ultrasound, and cytological aspiration.³²⁴⁶ This latter strategy may result in a benign to malignant biopsy ratio as low as 1:0·5. The specificity of radiological reporting to the patient, to the family practitioner, and to the surgeon must be high with minimal equivocation.⁴⁷

A low specificity in any part of a screening service will give rise to a high benign biopsy rate and will be likely to bring the whole concept of screening into public disrepute. It will also cause unnecessary anxiety in patients.

How can these dangers be avoided? The danger is that screening centres will be established on a wave of emotion—or worse, for reasons of financial gain. Poor quality screening units should be actively discouraged. One method could be for centres to be licensed or registered with some tests of quality. These tests should look at the skill and enthusiasm of the radiological, radiographic, and other staff and the availability of dedicated mammographic apparatus and sec-

ondary investigation facilities, such as magnification mammography, ultrasound, localising techniques, and cytological aspiration. Furthermore, mammographic screening units should be closely associated with established breast cancer treatment teams. Screening will inevitably raise the workload for these teams and staffing levels will need to be increased. The screening centres should have their own computerised call, report, and recall systems and should be based at first in these NHS areas which have a good computerised family practitioner committee record system and a breast cancer register.

How should we proceed now? At present mammographic services in Britain are woefully inadequate, and the first task will have to be to raise these to an adequate level before considering the introduction of national breast screening services. This implies the provision of dedicated mammogram units with dedicated film processing in dedicated rooms in every district hospital—which will require an increase in the establishments of consultant radiologists and of radiographers. At present radiologists may be appointed to consultant posts with no experience of mammography. Clearly training facilities will be needed in this exacting branch of radiology to improve standards. Some form of quality assurance is mandatory, for poor quality mammography may be dangerous in causing false reassurance and may also lead to inappropriate surgery.

While radiologists will retain the final responsibility for maintaining quality control and interpreting mammograms, non-radiologists may be needed as primary film "readers" when population screening services are eventually introduced. Further studies on this aspect are necessary.

The existing centres of proved excellence should begin by offering screening programmes, centrally monitored, designed to answer some of the outstanding questions. Initially these need not be full population studies of invited women: they might be based on self referral facilities and open access for women with minimal symptoms through their family practitioners. Around 5% of women each year have breast changes or symptoms which merit mammographic examinations. Satellite or possibly mobile units (with quality being controlled by the approved screening centres) might gradually extend the area of population coverage.

Conclusion

Screening for breast cancer can save lives and young lives at that. At the very least the death of some women may be postponed for 10 years or more. The introduction of a screening service in Britain is therefore highly desirable, but it must be introduced gradually so that the requisite high standard is achieved. The most appropriate approach for each age group is still a matter of some debate. The question of who should pay is one on which there should be an informed public debate. We still need to collect a few more facts to enable the public to be adequately informed.

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