A MAMMOGRAPHY RISK-BENEFIT ANALYSIS

R.Borio*, A.Antonini*, P.Salvadori**, C.Pagliochini*, P.G.Pazzaglia+, A.Verdecchia**
* Università di Perugia; ** Istituto Superiore di Sanità, Roma; + USL di Perugia
Italy

INTRODUCTION

A cost-benefit analysis, performed according to ICRP recommendations[1], raises serious problems because it entails comparison of protection levels and non-homogeneous quantities such as detriments. A risk-risk approach would seem to be simpler because comparison is between the detriment incurred by introduction of a specific procedure and the detriment avoided by adoption of precisely that procedure. Mammography is a field in which the risk-risk assessment concept can be applied, as the probability of tumour formation induced by the examination process can be compared with that of finding already-formed tumours. Research aimed at evaluating the advisability and limitations of a generalized mammographic screening has therefore been carried out in Umbria, a region in central Italy.

METHODS

Methods used in a Japanese benefit-vs.-risk analysis of stomach cancer mass screening[2] were adapted to mammography in generalized and selective screening respectively. Loses in life-expectancy for screened and unscreened subjects were compared.

Now, when screening is performed, loss A in life-expectancy, as a function of age, can be expressed as:

$$A = P\left\{S + D\left[f(1-w) + (1-f)(1-w')\right]T\right\} \qquad (1)$$

where: P is the number of people screened; S is the loss due to mammography induction of tumours; D is the incidence rate (supposed constant) of breast cancer per year; f is the ratio of true positive mammographies: true breast cancer cases; w is the five-year survival probability of patients with breast cancer found in mass screening; w' is the five-year survival probability of non-screened patients with breast cancer, and T is average life-expectancy. Where cancer patients die, life-expectancy is assumed to be zero at the time of cancer detection.

Likewise, when screening is not performed, loss B in life-expectancy, as a function of age, can be expressed as:

$$B = PD\left[KS + (1-w')T\right] = N\left[KS + (1-w')\ T\right] \qquad (2)$$

where: K is the ratio between the number of patients with breast diseases and the number with breast cancer in hospitals and N=PD is the number of tumours found in the screened population.

As far as S is concerned, leukaemia induction risk being negligible with respect to breast cancer induction risk, (1) may be expressed as:

$$S = E \cdot R \cdot \Delta M \qquad (3)$$

where: E is the average dose equivalent to the breast; R is the incidence rate of breast cancer per unit dose; ΔM is the shortening of life-expectancy, T, due to induction of breast cancer and is a function of latent period L_1 and incidence period L_2: $\Delta M=0$ if $T<L_1$, $\Delta M=(T-L_1)^2/2L_2$ if $L_1<T<L_1+L_2$, $\Delta M=T-L_1-L_2/2$ if $T>L_1+L_2$.

Different rescreening intervals are taken into account by repeated use of Eq.(3). Therefore, screening is justified when B>A.

DATA SOURCES

Data relative to population resident in Umbria and average life-expectancy as a function of age group were derived from[3,4]. The incidence rate per year of breast cancer in the whole population was estimated by a statistical model based on breast cancer mortality in Umbria[5].

The selected population consisted of about 7 000 spontaneous women clients of a mammographic centre in Perugia who were then selected for mammography on the basis of physical examination results and common risk factors. From clinical reports of the mammographic centre, numerical values were derived for: incidence of breast cancer in the selected population as a function of age group; ratio of true positive mammographies to true breast cancer cases (f=0.92); breast volume and density conditioning mammographic exposure, as a function of age group; five-year survival probability of patients with breast cancer found in the screening (w=0.72); five-year survival probability of non-screened patients (w'=0.60) as derived from follow-up data on patients with breast cancer detected by physical examination alone.

Average dose equivalent to the breast, as a function of age group, was evaluated by measurements obtained from Rando female phantom with TL dosimeters, under different technical conditions depending both on X-ray films used (with or without screens) and on volume of breast. Results showed breast dose per view ranging from 2 to 23 mSv (for non-screen films) or 0.4 to 4 mSv (for screen films), a negligible gonadal dose and a red bone marrow dose ranging from 0.25 to 1% of incident dose. The risk for breast cancer induction has been estimated to be $5 \cdot 10^{-3}$ Sv^{-1}, calculated according to ICRP No.26[1].

Latent period L_1 of radiation-induced breast cancer was taken to be 15 y and incidence period L_2 to be 30 y[2].

RESULTS

Different screening strategies, for breast cancer prevention by mammographic examination, are compared herebelow in terms of estimated cumulative benefit, defined as the sum of age-specific benefits over all the n age classes considered:

$$C = \Sigma_i (B_i - A_i) \qquad i = 1, \ldots, n. \qquad (4)$$

Strategies differ by the age of the first examination (16 to 76 years), periodicity of rescreenings (1-5 indicates years between two subsequent examinations; 0 indicates single examination with no repetition), X-ray dose used and by target population (selected high-risk population, general population).

To give an idea of how losses in life-expectancy combine to provide benefit (B-A), A and B, as defined in Eqs.(1) and (2), are reported in figs.1 and 2 as functions of general population age when screen films are used.

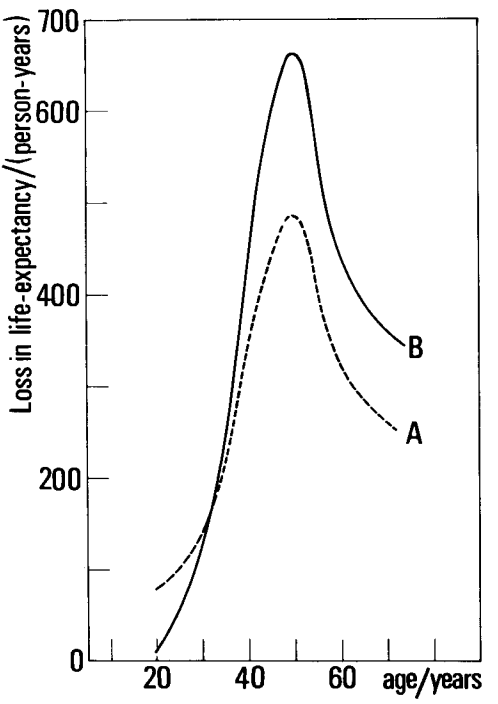

Fig.1 - Loss of life-expectancy in general population (A: single screening at age 16 y; B: no screening).

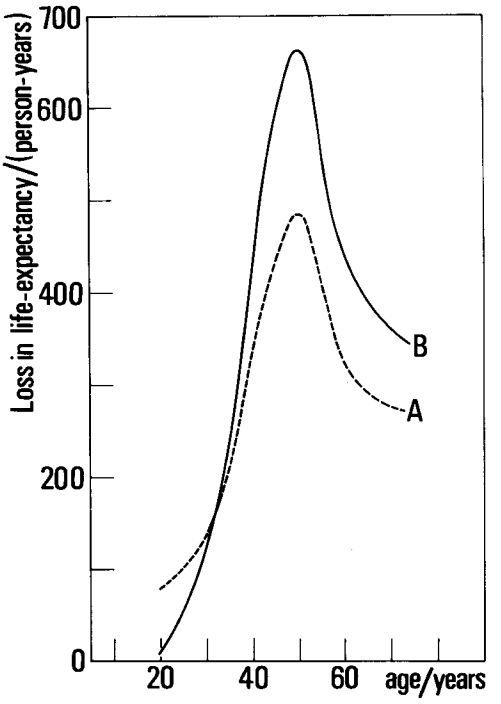

Fig.2 - Loss of life-expectancy in general population (A: screening with two-year interval, starting age 56 y; B: no screening).

For periodical screenings it has been assumed that a single examination also occurred in the population at age 16.

Table 1 show the estimated values of benefit for the different screening strategies considered for high-risk groups and the general population. Note that for single examination with no repetition it has been assumed that no other individual mammographic examination might ever occur in the population.

When the high-risk population is considered, maximum benefit is obtained for single examination at age 31, no matter what dose is used. As concerns the general population, maximum benefit is obtained again for single examination screening only at age 36 with screen films and at age 46 with non-screen films.

TABLE 1
Cumulative benefit/(person-years) of mammography screenings as a function of age at first examination and periodicity of rescreenings for two different commonly used X-ray doses.

age at 1st examination/years	Cumulative benefit/(person-years)							
	screen films				non-screen films			
	periodicity/years				periodicity/years			
	1	2	5	0	1	2	5	0
	a) selected high-risk population							
16	270.3	266.5	264.9	276.1	256.5	242.6	236.7	275.9
21	260.5	257.7	256.3	276.1	221.2	209.8	204.8	275.9
26	253.8	251.6	273.1	276.1	195.3	186.3	182.3	275.9
31	274.5	272.4	269.4	276.2	268.9	262.5	187.1	276.0
36	272.0	256.9	256.6	265.7	259.4	200.8	199.2	265.5
41	272.4	261.2	261.0	195.8	260.4	217.2	216.0	195.7
46	267.3	267.2	267.2	158.8	240.9	240.4	240.2	158.7
51	270.2	270.2	270.0	122.9	252.2	252.1	252.0	122.9
57	274.1	274.1	274.1	92.3	267.7	267.7	267.7	92.2
61	275.2	276.2	276.1	43.7	272.0	271.7	271.7	43.7
66	276.1	276.1	276.1	18.7	273.3	273.3	273.3	18.7
71	276.1	276.1	276.1	5.6	275.8	275.9	275.9	5.6
76	276.1	276.1	276.1	1.8	275.9	275.9	275.9	1.8
	b) general population							
16	-10900	-6244	-2194	492	-45568	-22659	-8914	250
26	-5598	-2514	-706	492	-22879	-11314	-4376	250
36	-1460	-487	-729	500	-9560	-4655	-1712	353
46	82	287	410	404	-1784	-767	-157	361
56	458	475	485	226	92	171	219	220
>65	492	492	492	103	250	250	250	102

CONCLUSIONS

Periodical generalized mammographic screenings seem to be justified when started at age 45 or over if screen films are used, and at age 55 or over if non-screen films are used. Single examination without repetition is always justified giving the absolute maximum benefit at ages 36 and 46, for screen and non-screen films, respectively. When a high-risk population is selected, any kind of screening appears to be justifiable, even though the absolute maximum benefit is reached when single, no-repetition examination is performed at age 31 for both doses considered.

REFERENCES

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