A retrospective review of the utility of Chest X-rays in diving and submarine medical examinations

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Abstract
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Introduction: Performance of routine chest X-rays (CXRs) in asymptomatic individuals to assess hyperbaric exposure risk is controversial. The radiation risk may overshadow the low yield in many settings. However, the yield may be higher in certain settings, such as tuberculosis-endemic countries. We evaluated the utility of routine CXR in diving and submarine medical examinations in South Africa.
Methods: Records of 2,777 CXRs during 3,568 fitness examinations of 894 divers and submariners spanning 31 years were reviewed to determine the incidence of CXR abnormality. Associated factors were evaluated using odds ratios and a binomial logistic regression model, with a Kaplan-Meier plot to describe the duration of service until first abnormal CXR.
Results: An abnormal CXR was reported in 1.1% per person year of service, yielding a cumulative incidence of 6.5% (58/894) of the study participants. Only four individuals had a clinical indication for the CXR in their medical history. A range of potential pathologies were seen, of which 15.5% were declared disqualifying and the rest (84.5%) were treated, or further investigation showed that the person could be declared fit.
Conclusions: In South Africa, a routine CXR has a role to play in detecting abnormalities that are incompatible with pressure exposures. The highest number of abnormalities were found during the initial examinations and in individuals with long service records. Only four individuals had a clinical indication for their CXR during the 31-year span of our study. Similar studies should be performed to make recommendations in other countries and settings.

Introduction

Fitness-for-work evaluations comprise three components, namely (1) the ability to perform the inherent job requirements, (2) endurance to work the full shift and (3) absence of undue risk to self and others.[1] There is a considerable emphasis on the cardiorespiratory system during diving and submarine medical evaluations and chest x-rays (CXRs) are usually performed to exclude conditions that represent undue risk.[2] Some countries mandate annual CXR in divers and submariners while others (e.g., the Health and Safety Executive in the United Kingdom) recommend "*only upon clinical indication*".[3]

Exposure to ionising radiation carries obvious risk, described elsewhere.[4–6] International standards and guidelines for radiation safety are also available.[7–9] Many of these guidelines are now mandated through regulation in most countries, including South Africa.[10] Routine imaging studies may also uncover coincidental findings with unclear clinical significance, potentially leading to unnecessary disqualification from diving.[2] Conversely, coincidental findings may be valuable in isolated cases.[11]

Despite the risks, there is still a need to use radiological imaging on patients as part of diagnostic workup and treatment. There is however a paucity of information regarding the utility of routine radiological imaging performed on asymptomatic individuals as part of an occupational medical (fitness-for-work) programme in divers and submariners.[2,12] This is of particular importance in the South African context, where endemic diseases such as tuberculosis could lead to structural lung changes, considered incompatible with exposure to increased environmental pressure.[13] The main aim of this study was to evaluate the utility of routine CXR as a component of the fitness evaluation of persons in South Africa who would be exposed to increased environmental pressure as part of

their work. The study objectives included: to determine the incidence of abnormal CXR reports and describing the range thereof, to describe the incidence of false positive results and the subsequent response, and to determine whether the medical history and clinical examination indicated CXR imaging.

Methods

The study protocol was independently reviewed by two ethics committees, namely the Health Research Ethics Committee (HREC) of Stellenbosch University (Reference U18/04/011), and the Research Ethics Committee of the South African Military Health Services (SAMHS) (Reference 1MH/302/6/02.01.2018). Consent was thereafter obtained from the appropriate authority in SAMHS to access the study data.

The researchers retrospectively reviewed the clinical records of all individuals who underwent a diving and / or submarine medical examination employed in the South African National Defence Force (SANDF). All these examinations are performed by qualified diving medical officers and subsequently reviewed by senior medical officers at the Institute for Maritime Medicine. The employees are allocated a specific category based on their mustering. Divers have a '*D*' category and submariners an '*S*' category captured in the records. A fitness certificate has a 12-month maximum duration. Chest x-rays are usually performed with each medical, but some examiners opt out of requesting these, mainly due to radiation risk concerns. Apart from the routine fitness evaluations, all SANDF personnel and their families receive comprehensive medical services via the SAMHS at no cost. This includes all relevant paramedical and multidisciplinary services, and it is therefore exceptionally unlikely for personnel to have medical consultations outside of the SAMHS while in service. The medical records of each healthcare encounter (including clinical examinations, medical notes, special investigations, specialist reports, laboratory results, etc.) are kept indefinitely in an electronic format and can be retrieved for many years back.

The researchers reviewed all CXR reports of everyone with a '*D*' or '*S*' classification, denoting everyone who ever had a diving or submarine medical examination during the study period June 1987 to April 2018. Whenever an abnormality was reported on a CXR, all medical records of the individual for the preceding year were reviewed to determine whether there was a medical indication for the CXR, or whether an asymptomatic abnormality was detected by routine screening.

In order to minimise information bias, the researchers made use of all available resources, including hard copies of the fitness evaluation files, which are kept at the Institute for Maritime Medicine. The identification of study participants was based on the '*D*' and '*S*' categories, including those deemed permanently unfit during their initial medical – potentially as a result of CXR abnormalities. This ensured that everyone who ever had such a medical examination was included in the study, thus eliminating the healthy worker effect.

To determine the frequency of CXR abnormalities, the researchers calculated the incidence of having a first abnormal CXR report (to avoid multiple counts of the same individual), using the number of person-years in the study as denominator. Potential predictive factors available for analysis included the specific service branch, the sex and average age of participants while in diving or submarine service and their total duration of such service. The odds ratio (OR) of contingency tables (with 95% confidence intervals [CIs]) was calculated for individual categorical variables. Statistical significance of the associations was determined using the Chi-squared or Fisher's exact test. In addition, a binomial logistic regression model was used to determine variables associated with CXR abnormality. A significance level of 0.05 was used for all hypothesis testing. A Kaplan-Meier survival analysis was used to estimate the employment duration until first abnormal CXR.

Results

The study sample comprised every CXR performed on SANDF divers and submariners who had their first medical examination for diving or submarine service between June 1987 and April 2018. This included new recruits, as well as individuals transferring from other service units during this period. A total of 894 individuals were included in this study, of which 47% (n = 422) were divers, 51% (n = 451) were submariners and 2% (n = 21) were qualified for both. The participants' median age while in service was 27.6 (IQR = 23.7–33.8) years and they had a short median service duration of 3.3 (IQR 1–7.5) years (range 0 to 28.4) and similar between divers and submariners (P = 0.13). Only 6.7% (60/894) had service records exceeding 20 years, of which most (n = 43) were submariners. The study participants contributed a total of 5,281.4 person-years of service.

A total of 3,562 fitness-for-work examinations were performed on the study participants, including a total of 2,777 CXRs. There were thus 22% (785/3,562) examinations where the examining doctor did not request a CXR. Good source data existed for all study participants, with only 0.2% (5/2,777) CXRs not having a radiology report.

Seventy CXR abnormalities were reported in 6.5% (58/894) of the study participants (Table 1). The range of abnormal findings on the routine CXRs was similar between divers and submariners (P > 0.05).

Most (n = 50) had only one abnormal CXR reported, six individuals had two, one had three, and one individual had a series of six abnormal CXR reports (without fitness contraindication). Subsequent presentations of the same

Table 1
Number of particular chest X-ray (CXR) abnormalities reported for the first time among all study participants; ǂ – an individual with an abnormal CXR may present with more than one abnormality. Seventy distinct abnormalities were reported in the CXRs of the 58 individuals. The same abnormality reported in the same individual in subsequent examinations was not counted again

Chest X-ray abnormalities	Found in 58 participants with abnormal CXRs ǂ
Scarring/Fibrosis	16
Pleural thickening	6
Opacities	8
Bronchial wall thickening	8
Nodular opacities	6
Pulmonary cyst	4
Granulomas	4
Calcification	2
Pulmonary infection	3
Bronchiectasis	2
Possible active TB	1
Other	7
'Abnormal' (no detail)	3

abnormality in the same individual were not counted again and are not included in the results. The incidence of first abnormal CXR reports was thus 10.98 per 1,000 person years (or 1.1% per person year). Many abnormal CXRs (n = 34) were seen during the first diving or submarine medical examinations of study participants (Figure 1). This means that 58.6% (34/58) of all persons with abnormal CXRs were identified during their first medical (when they first joined as new recruits or during their first transfer from other service units).

However, when the total number of individuals who had CXRs performed at a specific career duration is included as denominator, the percentage of first presentation of abnormal CXRs at each career point, yields a different picture. Eleven percent of all study participants had an abnormal CXR at the time of their first medical examination, and high percentages were thereafter also seen during the fourth year (9.1%), ninth year (11.1%), twelfth year (13.3%), fourteenth year (20%), sixteenth year (20%), 18th year (40%), twentieth year (50%), 22nd year (16.7%) and 23rd year (10%) of service (Figure 2).

When considering the full cohort of divers and submariners, the survival analysis indicates that almost 20% of individuals would have an abnormal CXR after approximately 30 years of service (Figure 3).

Twelve of the 58 individuals presenting with an abnormal CXR were declared as unfit for work, of which 9 were because of the CXR findings (Table 2). This constitutes a predictive value (for being declared unfit because of an abnormal CXR) of 15.5%, including one case of active TB disease detected by routine examination. For the rest of the cases (84.5%) with abnormal CXRs, the findings during

Figure 1
Number of divers and submariners with a chest x-ray abnormality reported for the first time (n = 58) by length of service (no denominator)

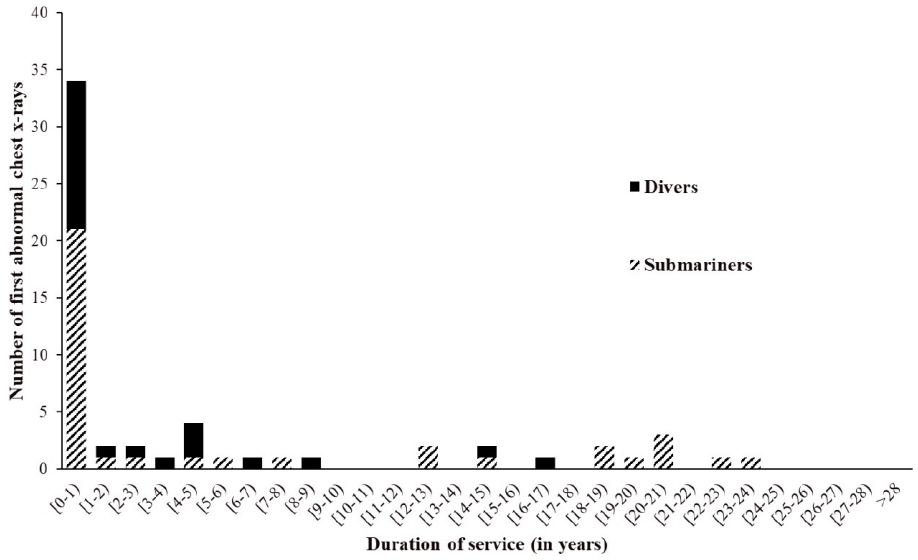

Figure 2
Percentage of divers and submariners with a chest X-ray abnormality reported for the first time (n = 58) by length of service of all study participants (n = 894)

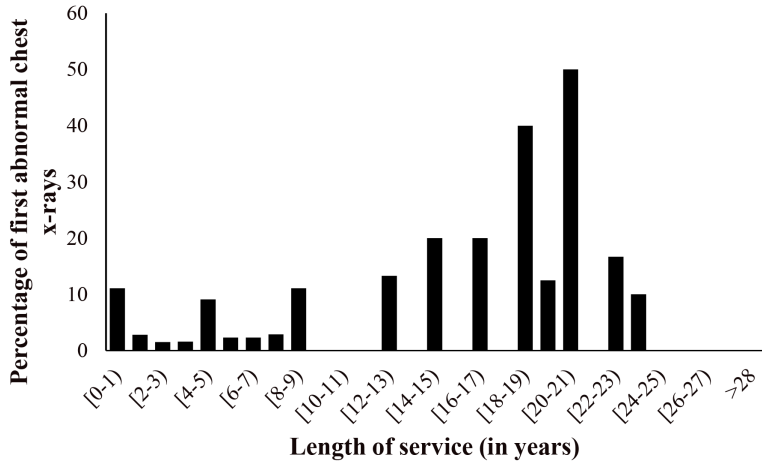

Figure 3
Survival analysis indicating duration of service until first report of an abnormal chest X-ray

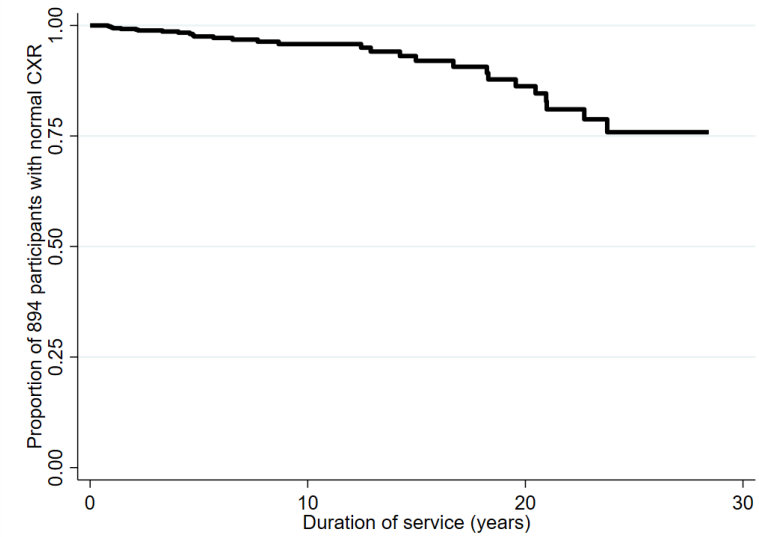

Table 2
Radiological follow-up of the 58 individuals with an abnormal CXR and impact on final fitness; § – one individual had both CXR and CT; CXR – chest X-ray; CT – computerised tomography; N/A – not applicable

Follow-up	Confirmed abnormal	Declared unfit
No follow-up (n = 31)	N/A	5
Follow-up CXR (n = 13)§	5	3
Follow-up CT (n = 15)§	4	4

follow-up evaluations denoted acceptable risk, and they were eventually declared fit for work.

When reviewing the full medical records of the preceding year for individuals presenting with an abnormal CXR, only 6.9% (4/58) had a possible clinical indication noted in their files, including one submariner who presented with respiratory symptoms and a diagnosis of active tuberculosis which was confirmed with CXR and sputum microscopy.

Thirteen percent of the study participants (n = 118) were female. However, sex did not constitute an independent risk factor (OR = 1.4, 95% CI = 0.7–3.2; P = 0.37). Submariners were more likely to present with CXR abnormalities than divers (OR = 2.2, 95% CI = 1.3–3.2; P < 0.01). The binary logistic regression model did not provide an adequate fit to the data (deviance = 242.6). Apart from the length of

service ($P < 0.05$), none of the variables could adequately predict CXR abnormality (including average age while in these service branches).

Discussion

The use of routine CXR is rightfully discouraged by several authors, particularly in low-risk settings.[2,14–19] In high-risk settings, routine CXRs are still advised.[20] Our study found a relatively high (6.5%) cumulative incidence of abnormal routine CXRs, and a very high proportion (up to 50%) were found to be abnormal in individuals with long service records. The Kaplan-Meier survival curve indicates that approximately one in five individuals with long service duration would be declared unfit for hyperbaric exposures. This curve should however be interpreted with caution, given the relatively short service duration of most study participants (median of 3.3 years).

Despite the high incidence of CXR abnormalities, only four individuals over the span of 31 years of our study had a clinical indication for CXR. A possible explanation is that divers and submariners would fail to report symptoms of illness for fear of losing their fitness certification. This is problematic for approaches using symptom-based screening (as recommended by others).[2] This problem is also recognised internationally among commercial divers and addressed in some detail in a publication of the International Marine Contractors Association (IMCA D 061).[21] This IMCA document provides examples of divers with severe illness who chose not to disclose this during medical examinations and in some cases, it resulted in fatality.

Individuals with longer service records have a higher probability of presenting with abnormal CXRs (irrespective of average age in service). The lack of association between length of service and age in our study is likely due to us using average age of individuals while serving in diving or submarine branches, rather than the average age over their full career. Some individuals have transferred from other service branches (e.g., surface vessels) and were only employed for very short diving or submarine service periods, while others spent their full career in these branches.

The association of abnormal CXR reports with service duration may indicate work-related pathology as a possible cause. Scarring, fibrosis, nodular changes and pleural thickening may be caused by specific occupational exposures (and included asbestos-related disease in some of our study participants). Apart from clinical (cardiopulmonary and other symptom) indications it is therefore also important to consider other risks, such as workplace exposures and a high prevalence of infectious diseases in the community, as indications for a CXR. For instance, nearly one quarter of tuberculosis cases among HIV-infected adults in South Africa were subclinical.[22] In a high prevalence setting, it is therefore conceivable that lung pathology can be present without the individual having symptoms to indicate the need for CXR. Furthermore, while numerous international policies propose screening based on symptoms as clinical indication, it is difficult to implement such a policy in a setting where there is a real incentive for employees to conceal their symptoms for fear of losing their fitness certification and jobs.[2] Computed tomography seems preferable in symptomatic individuals, but may result in unnecessary exclusions from work.[2] Similar dilemmas have been reported with routine CXRs in other settings.[23] Despite this concern, some countries still implement routine low-dose chest CT as part of military diver screening.[12] A checklist and clinical decision-making tool was recently developed to guide targeted baseline thoracic imaging in persons undergoing hyperbaric oxygen therapy.[24]

The apparent regular interval 'peaks' in our data for reporting a CXR abnormality (Figure 2) should be interpreted with caution, since CXRs were not requested in 22% of examinations and this examination was therefore not done with every annual fitness examination. These 'peaks' may thus represent information bias artifacts based on the frequency with which CXRs were requested.

Several variables that could potentially predict abnormal CXRs were not evaluated in our study. Some variables are prohibited by local legislation (e.g., HIV status, denoting increased risk for tuberculosis scarring, may only be tested in employees if sanctioned by the Labour Court).[25] Other variables (e.g., using race as proxy) were specifically excluded due to ethical concerns.[26] Future studies should consider a wider range of variables that may better predict the need for CXR and further refine indications for routine CXR, particularly including workplace risk assessments.

Conclusions

Our results indicate that there is a role for routine CXR in asymptomatic South African divers and submariners. The highest number of cases were found during the baseline (first medical) examination and in individuals with a long service history, suggesting that occupational exposures may play a role. While CXRs may be indicated based on the medical history of the individual, this was rarely the case in our study population, with only four cases thus detected in the 31-year span of our study.

We advise that similar studies be performed in other settings and other countries, to provide an evidence-based approach to the routine use of CXRs in occupational health fitness screening programmes.

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