ORIGINAL ARTICLE

Physician diagnosed asthma, respiratory symptoms, and associations with workplace tasks among radiographers in Ontario, Canada

G M Liss, S M Tarlo, J Doherty, J Purdham, J Greene, L McCaskell, M Kerr

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Background: Medical radiation technologists (MRTs) or radiographers have potential exposure to chemicals including sensitisers and irritants such as glutaraldehyde, formaldehyde, sulphur dioxide, and acetic acid.
Aims: To determine the prevalence of asthma and work related respiratory symptoms among MRTs compared with physiotherapists, and to identify work related factors in the darkroom environment that are associated with these outcomes.
Methods: As part of a two component study, we undertook a questionnaire mail survey of the members of the professional associations of MRTs and physiotherapists in Ontario, Canada, to ascertain the prevalence of physician diagnosed asthma, and the prevalence in the past 12 months of three or more of the nine respiratory symptoms (previously validated by Venables *et al* to be sensitive and specific for the presence of self reported asthma). Information on exposure factors during the past 12 months, such as ventilation conditions, processor leaks, cleanup activities, and use of personal protective equipment was also collected.
Results: The survey response rate was 63.9% among MRTs and 63.1% among physiotherapists. Most analyses were confined to 1110 MRTs and 1523 physiotherapists who never smoked. The prevalence of new onset asthma (since starting in the profession) was greater among never smoking MRTs than physiotherapists (6.4% *v* 3.95%), and this differed across gender: it was 30% greater among females but fivefold greater among males. Compared with physiotherapists, the prevalence of reporting three or more respiratory symptoms, two or more work related, and three or more work related respiratory symptoms in the past 12 months was more frequent among MRTs, with odds ratios (ORs) (and 95% confidence intervals) adjusted for age, gender, and childhood asthma, of 1.9 (1.5 to 2.3), 3.7 (2.6 to 5.3), and 3.2 (2.0 to 5.0), respectively. Analyses examining latex glove use indicated that this was not likely to account for these differences. Among MRTs, respiratory symptoms were associated with a number of workplace and exposure factors likely to generate aerosol or chemical exposures such as processors not having local ventilation, adjusted OR 2.0 (1.4 to 3.0); leaking processor in which clean up was delayed, 2.4 (1.6 to 3.5); floor drain clogged, 2.0 (1.2 to 3.2); freeing a film jam, 2.9 (1.8 to 4.8); unblocking a blocked processor drain, 2.4 (1.6 to 3.7); and cleaning up processor chemical spill, 2.8 (1.9 to 4.2). These outcomes were not associated with routine tasks unlikely to generate exposures, such as working outside primary workplace, loading film into processor, routine cleaning of processors, or removing processed film. Males reported that they carried out a number of tasks potentially associated with irritant exposures more frequently than females, consistent with the marked increase in risk for new onset asthma.
Conclusions: These findings suggest an increase of work related asthma and respiratory symptoms shown to denote asthma among MRTs, which is consistent with previous surveys. The mechanism is not known but appears to be linked with workplace factors and may involve a role for irritant exposures.

See end of article for authors' affiliations

Correspondence to: Dr G M Liss, Gage Occupational and Environmental Health Unit, 655 Bay Street, 14th Floor, Toronto, ON, Canada M7A 1T7; gary.liss@utoronto.ca

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Radiographers or medical radiation technologists (MRTs) have potential exposure to processing chemicals involved in developing and fixing films including sensitisers and irritants, such as glutaraldehyde, formaldehyde, sulphur dioxide (SO_2), and acetic acid.[1 2] The magnitude of the workforce is considerable, exceeding 5000 in Ontario and about 10 000 in Canada, which suggests that the sector includes several hundred thousand workers in North America and Europe. There have been case reports of occupational asthma (OA) among MRTs,[3–5] and two previous surveys have shown increased respiratory symptoms compared with physiotherapists.[6–8] Radiographers have also been reported to develop a poorly characterised condition known as "darkroom disease".[9] However, the prevalence of asthma and the mechanism (relative roles of sensitisation versus irritation) are unclear. Investigations from one centre showed glutaraldehyde specific antibodies in a minority of those with OA and with respiratory symptoms.[10 11] The extent of exposure to aerosols has been examined only rarely in previous exposure assessments.

Attention has focused on glutaraldehyde, as OA has been described in exposed health care workers in other professions, including a respiratory therapist,[12] and staff in endoscopy units[4 13 14] and renal dialysis.[15] However, in some studies, glutaraldehyde (GA) concentrations in darkrooms appear to be much lower than those measured in endoscopy suites.[4 16]

Abbreviations: CI, confidence interval; GA, glutaraldehyde; MRT, medical radiation technologist; OA, occupational asthma; OAMRT, Ontario Association of Medical Radiation Technologists; OR, odds ratio; PPE, personnel protective equipment; Respsx3m, three or more respiratory symptoms; WR, work related; WRresp2m, two or more work related respiratory symptoms

For example, GA exposures ranged from 0.003 to 0.006 mg/m^3 (0.0009 to 0.002 ppm) in darkrooms in the United Kingdom but were higher (up to 0.7 mg/m^3) in endoscopy suites. Gannon and colleagues[4] measured median personal short term GA concentrations of 0.016 mg/m^3 and long term concentrations of 0.041 mg/m^3 in endoscopy units, but in *x* ray darkrooms, the results of all 19 samples were less than 0.009 mg/m^3. Low exposures of radiographers were also documented in a recent investigation from British Columbia, Canada,[17] with average GA, acetic acid, and SO_2 concentrations of 0.0009 mg/m^3, 0.09 mg/m^3, and 0.08 mg/m^3, respectively.

This Ontario MRT study has two components. The objectives of the first component, described here, were to determine the prevalence of asthma and work related respiratory symptoms among members of the Ontario Association of Medical Radiation Technologists (OAMRT); assess whether the prevalence of these conditions is greater than among a control group of physiotherapsts; and if so, examine self reported exposure and work factors in the darkroom environment that are associated with these outcomes. In the second phase, which will be reported separately, we are conducting physiological confirmation of physician diagnosed asthma and work related asthma-like symptoms in a subset of those with these conditions; seeking serological evidence of an immunological mechanism; and characterising the current exposure conditions in a sample of work settings.

METHODS

We undertook a cross sectional questionnaire mail survey to ascertain the prevalence of asthma and respiratory symptoms, among MRTs compared with a control group of physiotherapists. The proposal received ethics approval from the Office of Research Services, University of Toronto.

Subjects

Subjects were recruited from members of the two professional associations, the OAMRT and the Ontario Physiotherapy Association (OPA). Our prestudy power calculations were based on an estimated target population for each profession of approximately 3000 members, 90% currently working, an anticipated response rate to the questionnaire of at least 50%, and estimated prevalence of outcomes of 5–7% in the comparison group. This would provide groups greater than that required (about 400–550) to detect a doubling of respiratory symptom outcomes, at an alpha level of 5% and 80% power. Of the four subgroups within the OAMRT, we included in our sampling frame only the 2700 radiological technologists (excluding radiation therapists, nuclear medicine technologists, and magnetic resonance imaging technologists). For the OPA, we excluded from the sampling frame a minority (about 10%) who had elected not to be approached for unsolicited mailings. This left more than 3000 members, so a random sample of 3000 was selected for mailing.

Questionnaire

The questionnaire was adapted from those used in the previous surveys by Smedley and colleagues[6] and Wymer and colleagues,[8] who kindly provided their instruments, plus input from the OAMRT. We included questions common for both professions regarding demographics, dates of training and starting work, shifts, hours, respiratory and other symptoms, questions regarding chemical sensitivity, psychosocial factors, and smoking history. The questionnaire for MRTs included questions (mostly for the past 12 months) regarding ventilation conditions, *x* ray processing tasks, leaking processors, clogged drains, cleanup activities, and personal protective equipment (PPE). The questionnaire also included items dealing with workplace psychosocial factors and musculoskeletal symptoms, which are currently being analysed. The questionnaire was pilot tested with 15 MRTs, following which several awkward questions were revised. The covering letter indicated that this was a study of health and safety of various health professions and did not indicate a focus on respiratory problems or on MRTs. We conducted an initial mailing in late October 2000 with a reminder card one month later, followed by a second mailing in January 2001 to non-respondents with another reminder card one month after that. Questionnaire printing, distribution, and data entry were conducted by the Institute for Social Research, York University, Toronto.

Respiratory system outcomes

Physician diagnosed asthma

This was defined as positive responses to both "Have you ever had asthma" and "Was it confirmed by a doctor?".

New onset asthma

This was defined as meeting the conditions for physician diagnosed asthma and reported onset after starting practice as an MRT or physiotherapist.

Respiratory symptoms in past 12 months

We incorporated questions for the prevalence during the past 12 months based on the nine respiratory symptoms for which two or three positive responses were previously validated by Venables and colleagues[18] to be sensitive and specific indices for the presence of self reported asthma and bronchial hyperresponsiveness (see Appendix). For those answering affirmatively to a given symptom, we assessed whether the symptom was work related, based on the response to the additional question "while away from work how often does [the symptom] occur? ...". We considered a symptom to be work related (WR) if the respondent indicated that this occurred less frequently than on workdays or not at all, as adapted from questionnaires used in previous hazard evaluations in Ontario and at NIOSH.[19–21] We determined the prevalence of three respiratory symptom outcome measures: three or more respiratory symptoms; two or more WR symptoms; and three or more WR symptoms. Current smokers answered affirmatively to "Have you ever smoked cigarettes (at least one cigarette a day for one year)?" and "Do you currently smoke cigarettes?"; ex-smokers answered affirmatively to the first question and negatively to the second.

Statistical analysis

We compared proportions of categorical variables between the two exposure groups with χ^2 tests, and continuous variables with *t* tests. We initially conducted contingency table analyses and considered interactions by assessing the Breslow-Day test for the homogeneity of the odds ratios. Where interactions occurred, stratified results are presented. To compare the prevalence of physician diagnosed asthma between MRTs and physiotherapists, we stratified by age (in three groups) and gender, while analyses of respiratory symptoms were also adjusted for childhood asthma (defined as physical diagnosed asthma with onset less than 16 years of age). The relative risk was estimated by the Mantel-Haenszel odds ratio (OR). We subsequently used the OR from unconditional multiple logistic regression analyses to estimate the risk for respiratory system outcomes between the professions, adjusting our models simultaneously for potential confounders such as age, gender, and childhood asthma. We also used logistic regression analysis to identify, among MRTs, possible workplace/exposure factors associated with respiratory outcomes, while adjusting for the same confounders. Including the age term in either three groups or as a continuous variable yielded almost identical results; the latter are presented. Given that multiple comparisons with exposures and tasks were made, we arbitrarily considered associations with exposures to be "of note" or clinically important if the ORs were 1.8 or greater and the 95% confidence interval (CI) excluded unity. As the workplace and

Table 1 Characteristics of never smokers

Characteristic	MRTs (n=1110)*	Physiotherapists (n=1523)*
Continuous; mean (SD) [range]		
Age	41.3 (9.7) [21–69]	38.2 (9.8) [22–71]
Years practice	17.7 (10.0) [0.5–49.6]	13.7 (9.8) [0.08–46.8]
Categorical (%)		
Gender (% female)	88.7%	84.4%
Childhood asthma (%)	4.4%	5.6%
Dayshift (%)	62.5%	87.3%

*MRT, medical radiation technologist; data not available for small proportion for some variables (<10 in each group).

task exposure variables are all dichotomous, the regression coefficients in tables 4 and 5 represent the comparison between "yes" and "no" in all cases. In additional analyses, we further adjusted the above comparisons between the professions for latex glove use, and compared latex associated symptoms among MRTs versus physiotherapists. Most analyses were confined to never smokers who comprised the majority of both professions. For comparisons of asthma and respiratory outcomes between the professions, we also examined the former and current smoking groups separately. All statistical analyses were conducted using SAS version 8 (SAS, 2000).

RESULTS

Questionnaire responses

Of the 2761 and 3000 questionnaires distributed to the MRTs and physiotherapists, respectively, there were "bad addresses/returned to sender" responses for 15 and 24; and "bad sample units" (deceased, not working, out of country) for 0 and 6, respectively. Of the remaining 2746 and 2970 members, completed questionnaires were received from 1754 and 1875, yielding response rates of 63.9% among MRTs and 63.1% among physiotherapists, respectively. We then excluded respondents who indicated that their work was totally administrative (34 MRTs and 27 physiotherapists) or that they were currently on sick leave (one MRT), leaving 1719 and 1848, respectively. We confined most analyses to the 1110 (65.1%) MRTs and 1523 (82.9%) physiotherapists who never smoked and did not spend all their time in administrative positions. Among the never smokers, the MRTs were older and had been in practice longer, were slightly more likely to be female, and were less likely to work on day shift (table 1). The MRTs were somewhat less likely to have had childhood asthma. Age and years in practice were highly correlated among both MRTs ($r = 0.90$) and physiotherapists ($r = 0.94$).

Comparison of main outcomes between MRTs and physiotherapists

Physician diagnosed asthma

Never smokers

Although the prevalence of physician diagnosed asthma was similar in both groups (table 2), the prevalence of physician diagnosed asthma with new onset since starting work in the profession was greater among MRTs than physiotherapists (6.4% *v* 3.95%). However, there was an interaction across gender (table 2). The age adjusted prevalence of new onset asthma was about 30% greater among females, but was fivefold greater among males (age adjusted OR 5.3; 95% CI 1.4 to 20.2; $p < 0.05$).

Ex- and current smokers

There were few respondents for analysis (table 3). Physician diagnosed asthma was less frequent among MRTs than physiotherapists among both ex-smokers (10% *v* 14%; OR 0.6) and current smokers (9.0% *v* 16.3%; OR 0.5). New onset asthma

Table 2 Asthma and respiratory symptoms in MRTs and physiotherapists, among never smokers

Outcome	MRTs (%)	Physios (%)	OR (unadj)	OR adj (95% CI)
Asthma				
Physician diagnosed asthma	13.3	13.8	0.96	1.0* (0.8 to 1.3)
New onset asthma	6.44	3.95	1.7†	F: 1.3 (0.9 to 1.9)‡
				M: 5.3 (1.4 to 20.2)‡
Respiratory symptoms past 12 months ††				
3 or more of 9	20.9	12.6	1.9	1.9§ (1.5 to 2.3)
				1.9¶ (1.5 to 2.5)
				1.9** (1.5 to 2.4)
2 or more WR	11.1	3.1	3.9	3.7§ (2.6 to 5.3)
				4.2¶ (2.8 to 6.1)
				3.9** (2.6 to 5.5)
3 or more WR	6.1	1.9	3.5	3.2§ (2.0 to 5.0)
				3.5¶ (2.1 to 5.7)
				3.4** (2.1 to 5.5)
Latex associated symptoms ††				
Latex skin	11.2	5.3	2.3	2.5 § (1.9 to 3.4)
Latex nose	7.0	2.9	2.5	2.7 § (1.8 to 3.9)
Latex eye	5.3	1.9	2.9	2.8 § (1.8 to 4.5)
Latex wheeze, SOB, CT	2.5	0.9	2.8	2.7 § (1.4 to 5.2)
Latex (any of eye, nose, wheeze)	9.1	3.6	2.7	2.8 § (2.0 to 4.0)

*Adjusted for age and gender.
†Significant interaction with gender (p=0.016).
‡Adjusted for age.
§Adjusted for gender, age, and childhood asthma.
¶Adjusted for gender, age, childhood asthma, and latex glove use.
** Among those not reporting latex associated wheeze, SOB, or chest tightness (adjusted for age, gender, and childhood asthma).
††All p values in this section <0.0001 except for latex wheeze, SOB, CT, for which p=0.0032.
CI, confidence interval; SOB, shortness of breath; CT, chest tightness.

Table 3 Respiratory system outcomes among ex and current smokers

Outcome	Ex smokers			Current smokers		
	MRT/physio	OR_U	OR_A (95% CI)	MRT/physio	OR_U	OR_A (95% CI)
n	410/265			178/ 49		
Asthma						
Physician diagnosed asthma	10%/14.0%	0.7	0.6* (0.4 to 1.0)	9.0%/ 16.3%	0.5	0.5* (0.2 to 1.2)
New onset asthma	5.4%/5.3%	F 1.0 M No cases	1.1† (0.5 to 2.1)	4.5%/ 4.1%	F 0.8 M 1 (4.6%) of 22 MRTs; no cases in 8 physios	1.0 † (0.2 to 5.0)
Respiratory symptoms past 12 months						
3 or more of 9	17.1%/14.3%	1.2	1.4‡ (0.9 to 2.1)	30.9%/16.3%	2.3	3.2 ‡ (1.3 to 8.0)
2 or more WR	12.0%/4.9%	2.6	3.0‡ (1.5 to 5.9)	16.3%/6.1%	3.0	3.5‡ (0.96 to 12.7)
3 or more WR	7.3%/2.3%	3.4	3.3‡ (1.3 to 8.1)	10.7%/4.1%	2.8	3.0‡ (0.7 to 13.8)

*Adjusted for age and gender.
†Adjusted for age.
‡Adjusted for age, gender, and childhood asthma.
OR_U, odds ratio unadjusted; OR_A, odds ratio adjusted; CI, confidence interval.

could be analysed only among females, since there were no cases among the 47 male MRTs and 28 physiotherapists who were ex-smokers, and among the eight male physiotherapists currently smoking; there was one (4.6%) case among the 22 MRTs currently smoking. After adjusting for age, there were similar proportions of females in the two professions with new onset asthma, both in former (OR 1.1) and current (OR 1.0) smokers (table 3), indicating lower proportions (by subtraction) of MRTs with asthma of onset prior to starting work.

Prevalence of respiratory symptoms in past 12 months

Among never smokers, after adjusting for age, gender, and childhood asthma, MRTs were twice as likely to report three or more of the nine marker respiratory symptoms, and were over three times more likely to report two or more, or three or more WR respiratory symptoms (table 2). These associations were observed among both those with and those without childhood asthma (data not shown). Similar patterns of increased prevalence of respiratory symptoms among MRTs were also shown among ex-smokers and current smokers (table 3).

Latex glove use and symptoms

MRTs were slightly more likely than physiotherapists to report ever using latex gloves in the past 12 months (75.2% *v* 71.3%; $p = 0.03$) and much more likely to use them always or usually than rarely or never (49.2% *v* 16.5%; $p < 0.0001$). However, the increased risks for reporting respiratory symptom outcomes were little changed when further adjusted for latex glove use (table 2); the relative risks were somewhat greater among those not using than among those using these gloves (data not shown). MRTs were also more than twice as likely to report latex associated symptoms than physiotherapists; however, the increase in all three respiratory symptom outcomes persisted among MRTs when the analysis was limited to those not reporting latex associated wheeze, shortness of breath, or chest tightness (table 2).

Table 4 Examples of work tasks/exposures in past 12 months not associated or only weakly associated with respiratory symptoms among MRTs

Work task/exposure	3 or more respiratory symptoms OR* (95% CI)	2 or more WR respiratory symptoms OR* (95% CI)
Workplace factors		
Work outside primary workplace	1.1 (0.7 to 1.7)	1.3 (0.8 to 2.3)
Exhaust outlets	0.9 (0.5 to 1.5)	0.8 (0.4 to 1.4)
Silver recovery unit	0.8 (0.4 to 1.5)	0.6 (0.3 to 1.4)
Tasks and exposures		
Load film into daylight processor†	1.2 (0.8 to 1.7)	1.6 (1.0 to 2.6)
Load film in a darkroom†	1.2 (0.8 to 1.9)	1.7 (0.9 to 3.3)
Films per day (dichotomised at median, ≤60 *v* >60)	1.2 (0.9 to 1.6)	1.5 (1.0 to 2.2)**
Remove processed film from auto processor†	1.1 (0.7 to 1.9)	0.7 (0.4 to 1.3)
Pour processing chemicals‡	1.3 (0.9 to 1.7)	1.4 (0.9 to 2.1)
Processing film by hand (wet developing)‡	1.2 (0.7 to 2.2)	(see table 5)
Removed used chemicals	1.6 (1.1 to 2.3)**	1.0 (0.6 to 1.8)
Clean processor (routine)‡	1.5 (1.1 to 2.1)**	1.4 (0.9 to 2.1)
Clean crossover rollers‡	1.0 (0.8 to 1.4)	1.1 (0.7 to 1.7)
Mix fixer/developer chemicals‡	1.2 (0.9 to 1.7)	1.6 (1.1 to 2.4)**
Personal protective equipment		
Gloves when loading or replacing chemicals§	1.1 (0.7 to 1.8)	1.4 (0.8 to 2.5)
Gloves for other tasks§	0.9 (0.6 to 1.3)	0.8 (0.5 to 1.3)
Latex gloves¶	0.7 (0.5 to 1.0)	0.6 (0.4 to 0.96)**
Goggles when loading or replacing chemicals§	1.1 (0.6 to 1.9)	1.7 (0.9 to 3.2)
Gown when loading or replacing chemicals§	1.3 (0.7 to 2.4)	1.6 (0.8 to 3.4)
Respirator (not disposable) when adding developer or fixer¶	1.3 (0.8 to 2.3)	1.5 (0.8 to 2.9)
Lead apron¶	1.1 (0.6 to 1.9)	1.1 (0.5 to 2.2)

*Odds ratio adjusted for age, gender, and childhood asthma.
†≥1/wk and daily *v* never and <1/wk.
‡<1/wk or more *v* never.
§Always *v* usually, rarely, never.
¶At least rarely *v* never.
**p< 0.05.

Table 5 Examples of work tasks/exposures associated with respiratory symptoms among MRTs

Work task/exposure	3 or more respiratory symptoms OR* (95% CI)	2 or more WR respiratory symptoms OR* (95% CI)
Workplace		
Machines have LEV (all *v* none, some, most)	0.5 (0.3 to 0.7)	0.6 (0.4 to 0.9)**
Ventilation in area where films processed perceived as adequate (*v* inadequate)	0.5 (0.4 to 0.7)	0.4 (0.2 to 0.5)
Tasks past 12 months		
Processor leak	1.5 (1.0 to 2.2)**	1.6 (0.98 to 2.6)¶
Delay of clean up >1 day	2.4 (1.6 to 3.5)	2.1 (1.3 to 3.3)
Floor drain clogged	1.7 (1.2 to 2.4)	2.0 (1.2 to3.2)
Free a film jam†	2.3 (1.5 to 3.4)	2.9 (1.8 to 4.8)
Unblock blocked processor drain‡	2.4 (1.6 to 3.7)	1.8 (1.0 to 3.0)**
Processing film by hand (wet developing)‡	– (see table 4)	2.1 (1.1 to 4.0)**
Clean up processor chemical spill‡	2.0 (1.4 to2.7)	2.8 (1.9 to 4.2)
Detect odour of processing chemicals in work area§	1.8 (1.3 to 2.5)	2.8 (1.7 to 4.5)

LEV, local exhaust ventilation. *Odds ratio adjusted for age, gender, and childhood asthma. †≥1/wk and daily *v* never and <1/wk. ‡<1/wk or more *v* never.§Few times/month, weekly, and daily *v* never and rarely. ¶0.05<p<0.1. **p<0.05 (all other p values <0.01).

Work tasks/exposures and respiratory symptoms among MRTs

As the prevalence of asthma and respiratory symptoms was shown to be increased among the MRTs, we then explored among the never smokers, the associations of workplace factors, tasks, and exposures of the MRTs during the past 12 months with two of these outcomes: three or more respiratory (Respsx3m), and two or more WR respiratory symptoms (WRresp2m).

Workplace factors and exposures not associated or only weakly associated with respiratory outcomes

Workplace factors

There was no association with working as an MRT outside the primary workplace, or reporting the presence of air supply inlets or air exhaust outlets, or a silver recovery unit (table 4).

Tasks and exposures (table 4)

There were only weak or no associations (OR <1.8) with the frequency of loading film into a daylight processor or in a darkroom, removing processed film from an automatic processing machine, pouring processing chemicals, processing film by hand (for Respsx3m), removing used chemicals, mixing fixer/developer chemicals, routine processor cleaning (racks, tanks—periodic servicing), and cleaning the crossover rollers of a processor (usual quality control). There was only a weak association with the number of films processed per day, dichotomised at the median. Of note, many of these are routine tasks or activities that are unlikely to generate aerosol or chemical exposures, although pouring and mixing chemicals might be considered to be exceptions.

PPE

The respiratory outcomes were not associated with using various types of PPE (table 4).

Workplace factors and exposures associated with respiratory outcomes

Workplace factors

It was reported that all processing machines (compared with some or none) having local exhaust ventilation (LEV), and the perception that the ventilation in the area where films were processed was adequate (versus inadequate) were associated with a significantly reduced risk of respiratory symptoms (table 5).

Tasks and exposures (table 5)

Although there were only weak associations with reporting that a processor leaked in the past 12 months, a delay in the clean up for greater than one day was associated with more than a doubling of these outcomes. The outcomes were also significantly associated with the floor drain being clogged, and the frequency of freeing a film jam, unblocking a blocked processor drain, processing film by hand or wet developing (for WRresp2m), and detecting the odour of processing chemicals in the work area. While the frequency of routine cleaning of processors and cleaning crossover rollers was not associated with these outcomes (table 4), cleaning up a processor chemical spill was strongly associated (table 5). For a number of these outcomes, the associations were stronger for the work related outcome than for simple respiratory symptoms, and many of these activities may generate chemical exposures in vapour or aerosol form. A number of gender specific ORs were greater among males than females, but the interaction terms were not statistically significant (data not shown).

Frequency of exposure by gender

Because gender modified the prevalence of new onset asthma, we also examined how the reported frequency of exposures or tasks varied by gender, during two time windows: in the past 12 months and "in 1995 or earlier" as a snapshot of conditions "five years ago or more". Males and females reported similar frequencies for mixing chemicals, removing processed film, loading film in a daylight processor or a darkroom, and cleaning crossover rollers (usual quality control of processor) during 1995 or earlier. However, males were significantly more likely to report freeing a film jam, periodic servicing of processor involving racks and tanks, cleaning processor chemical spills, unblocking processor drain, removing used chemicals, processing film by hand, and pouring chemicals (fig 1). Similar reporting patterns were observed for responses related to the past 12 months (data not shown). Moreover, among males, those with new onset asthma were more likely than those without respiratory symptoms to report freeing a film jam (50% *v* 34.5%), removing used chemicals (40% *v* 24.1%), wet film developing or processing film by hand (62.5% *v* 31.5%), and cleaning processing chemical spill (70% *v* 52.6%), referring to 1995 or earlier. Those with new onset asthma were also more likely to report periodic servicing of processor in the past 12 months (50% *v* 34%) and were less likely to perceive that the ventilation in the area where films were processed was adequate (42.9% *v* 70.9%).

Occurrence of new onset asthma over time

Using five year groupings, subjects in each profession were classified according to the time period since starting work. We then determined the proportion of respondents with new onset asthma in relation to all respondents starting work in a given time period (fig 2). Among those starting prior to 1985, there was a tendency for the proportion of new onset asthma to be greater among the MRTs (exceeding 7 per 100 in all four

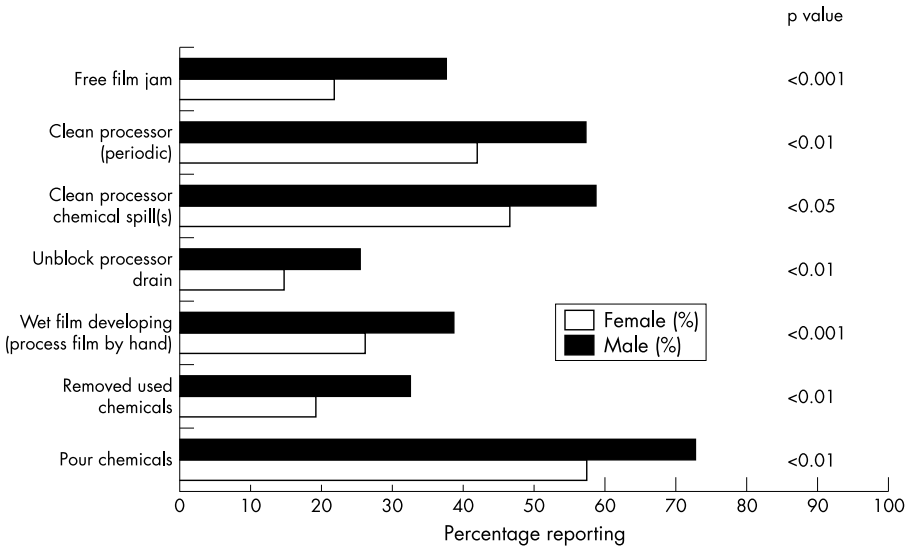

Figure 1 Activities/exposures among medical radiation technologists, by gender, during 1995 or earlier, for those activities reported significantly more frequently among males.

time periods and 8 per 100 in two periods) than among physiotherapists (exceeding 7 per 100 in only one period and 8 per 100 in none). On the other hand, the proportion was approximately 4 per 100 or lower in both professions among those starting in recent time periods. Similarly, the ratio of the proportions of new onset asthma across professional groups (MRTs/physiotherapists) was greater (≥1.5) in three of the four periods prior to 1985, but was close to unity in both of the recent time periods in 1985 or after (fig 2).

DISCUSSION

The present study, which is comparable in size to that of Smedley and colleagues,[6] represents one of the largest population based surveys among radiographers to date, and is the first to incorporate immunological analyses, which are in progress. In this report, we have highlighted self reported asthma and respiratory symptom outcomes among MRTs.

Asthma

Among never smokers, who comprised the majority of respondents, the two professions did not differ in the overall prevalence of physician diagnosed asthma; however, the prevalence of new onset asthma since starting work was greater among the MRTs, and gender modified this association. The association among females was weak and not statistically significant, although if causal, this may be of public health significance given the very large numbers in the profession. On the other hand, among males, after adjustment for age, the prevalence of new onset asthma was five times greater among MRTs than among physiotherapists. The reasons for this are not known; however, in the past, male MRTs were more frequently assigned to work with processing chemicals and carrying the chemical tubs, which may have played a role in the increased risk observed (R Hesler, Executive Director, OAMRT; personal communication, 2001). Moreover, in our survey, a number of exposures and tasks were reported significantly more frequently by males than females (fig 1), and also among males, more frequently by those with new onset asthma than those without respiratory symptoms.

Among the smaller numbers of current and ex-smokers, the overall prevalence of physician diagnosed asthma among MRTs was only about half of that among physiotherapists, and the prevalence of new onset asthma was similar in the two professions. Thus, by subtraction, there were far fewer MRTs who had asthma with onset in childhood or prior to work. This suggests that MRTs with asthma may have left the profession prior to this survey as a result of workplace conditions such as respiratory irritants which are known to be present in their work setting but not in that of physiotherapists. Monso and colleagues[22] recently reported health related self selection in a prospective study of apprentices exposed to high molecular weight agents, supporting the hypothesis of attrition bias in the natural history of OA.[23] In addition, our observation that there was a higher proportion with new onset asthma among

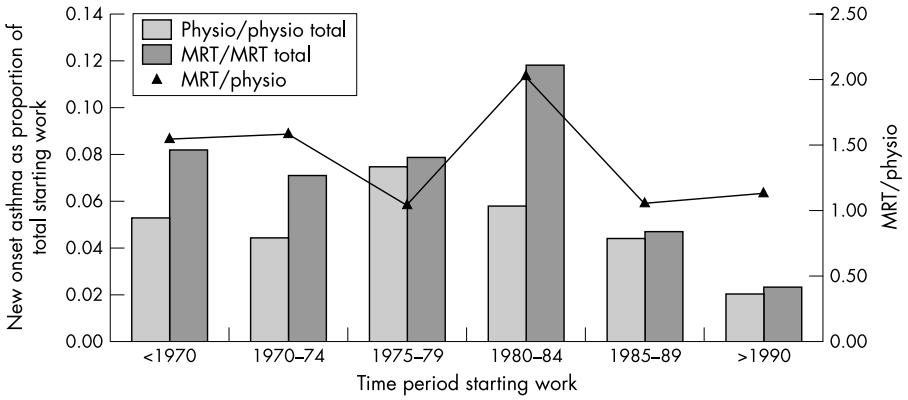

Figure 2 New onset asthma as a proportion of all respondents, among medical radiation technologists and physiotherapists, according to time period starting work.

MRTs than among physiotherapists prior to 1985 (fig 2), suggests that working conditions were worse in the earlier years, with some improvement in the past 15 years.

Respiratory symptoms in past 12 months

We observed a moderately strong association among MRTs compared with physiotherapists for reporting respiratory symptoms previously shown to denote asthma, and these increased in strength to more than threefold greater risk for work related symptoms. Latex associated symptoms were reported more frequently among MRTs (table 2). In fact, Wymer and colleagues[8] observed an identical OR of 2.7 for "latex allergies". However, these latex related symptoms were reported by less than 10% of the entire group (≤2.5% for lower respiratory symptoms; table 2), and the increased risks among MRTs persisted after further adjustment of the regression models for reported latex glove use, or when examined among those not reporting latex associated lower respiratory symptoms, suggesting that latex allergy cannot explain these findings.

Associations of symptoms with tasks during past 12 months among MRTs

Among the MRTs, respiratory outcomes were associated with a number of workplace factors and tasks that may generate or exacerbate aerosol or chemical exposures (table 5). They were also associated with characteristics related to the adequacy of darkroom or processor ventilation, such as whether all processors had LEV, the perception of adequacy of ventilation, and the frequency of detecting odour of processing chemicals, factors that may play a role in their origin. This also suggests the possibility of overlap with sick building syndrome, which we have observed in separate analyses of non-respiratory symptoms (Tarlo *et al*, in preparation). In their examination of exposure determinants in radiographic film processing, Teschke and colleagues[17] found that the presence and flow rate of LEV were significant predictors of GA and SO_2 concentrations, but general room ventilation was not associated with contaminant reductions. Our observation that latex glove use in the past 12 months was not associated with respiratory symptoms (table 4) may reflect the fact that respondents who were sensitised may have already changed to non-latex gloves.

The strongest associations (ORs exceeding 2.3) that we observed were for delayed clean up of leaks, freeing a film jam, unblocking blocked processor, clean up of process spill, and detecting odour. On the other hand, there were weak or no associations with workplace factors or activities that were unlikely to generate (or be markers for) aerosol or chemical exposures, such as merely working in a second location outside of primary workplace, the number of films processed per day, or the frequency of loading film into a daylight loader, removing processed film, or the routine cleaning of processors. Moreover, the fact that MRTs did not link their respiratory symptoms with all workplace factors provides some specificity and reassurance against recall bias and a tendency to "over report" symptoms. It should be emphasised that the increased symptoms (table 2) and associations with workplace and exposure factors (table 5) refer to the past 12 months. Thus, despite the indication of recent improvement in conditions (fig 2), there is still substantial evidence for current problems.

Comparison to previous surveys

Smedley and colleagues[6] observed that the one year period prevalence for two or more asthma marker symptoms, based on the same questionnaire used here,[18] was 22.9% among radiographers versus 18.4% among physiotherapists (period prevalence ratio of 1.23 (1.09–1.40)), and that the lifetime prevalence of one or more of respiratory symptoms worse at work was 2.1 (1.6–2.4) times more frequent among radiographers. Wymer and colleagues[8] reported that among never smokers, several respiratory symptoms (woken by shortness of breath, regular breathing problem, and daytime shortness of breath) were 2.2–2.5 times more frequent among radiographers than physiotherapists, after adjustment for age, gender, and childhood asthma.

With respect to associations with exposures/tasks in previous surveys, Smedley and colleagues[6] examined associations of activities in the past year among radiographers with work related non-respiratory but not respiratory symptoms. The tasks that most consistently entered models for these symptoms were working for at least 20 hours a week in a room with an automatic processor, and working in a room where a machine was obviously leaking. Wymer and colleagues[8] found the strongest (two- to threefold) and most consistent associations of respiratory symptoms among never smoking radiographers with detecting odours and cleaning spills, similar to our findings.

Might the associations observed in our study be causal? Considering the Bradford Hill criteria,[24] the associations that we observed (both between the professions and among the MRTs) are moderately strong, and consistent with findings in the two previous surveys[6 8] as well as with prior case reports. These associations are also biologically plausible given the presence of irritants and sensitisers in the darkroom environment. There is some indirect evidence for dose-response relations in that (a) the associations were much stronger for work related symptom clusters than merely three or more respiratory symptoms; (b) there were much stronger associations with delayed clean up of leak compared with simply reporting a leak; and (c) there was a pattern of links with tasks or factors likely to generate chemical or aerosol exposures, but an absence of associations with tasks unlikely to generate exposures. Although temporality cannot be established in cross sectional studies, it is suggested by the greater prevalence among MRTs for new onset asthma but not for simple physician diagnosed (or childhood) asthma (this evidence was limited to never smokers).

This investigation is limited by the cross sectional design in which one cannot confirm temporality, and the subjective nature of the questionnaire (asthma and symptoms; exposures or tasks, which have not been confirmed). However, of those reporting a diagnosis of physician diagnosed asthma who underwent confirmation, at least half of both MRTs (six of 12) and physiotherapists (seven of 10) had positive methacholine challenge tests ($PC_{20} \leq 8$ mg/ml),[25] confirming current bronchial hyperresponsiveness. The self reported survey data are also limited by the potential for recall bias; participants with symptoms may overestimate their exposures. On the other hand, as in cross sectional studies in general, if symptomatic MRTs tended to leave work, the magnitude of risks may be underestimated. This is suggested by the marked deficit of asthma with onset prior to starting work among ever smoking MRTs. Confounding due to smoking is possible when examining respiratory symptoms. We addressed this by looking at the asthma and respiratory symptom outcomes separately by smoking status, and by limiting most analyses to the much larger group of never smokers. The strengths of our investigation include the large sample size, the reasonable response rate for a mail survey which was comparable between the groups, the utilisation of a previously validated asthma symptom questionnaire, and the incorporation of a second laboratory and field component with objective confirmation of asthma and its work relatedness in a sample of respondents, and the characterisation of a sample of darkroom environments.

In summary, the findings of increased new onset asthma among never smokers suggest that there may be an increase in work related asthma among MRTs. The increase of respiratory symptoms shown to connote asthma among MRTs, plus the associations with tasks and scenarios likely to generate aerosol or chemical exposures but not with a number of routine

Key messages

- New onset asthma since starting work in the profession was greater among radiographers (or MRTs) than among physiotherapists, particularly among males.
- The prevalence in the past 12 months of respiratory symptoms shown to be sensitive and specific indices for asthma were reported 2–3 times more frequently by MRTs than physiotherapists; associations were stronger for work related symptoms.
- Sensitisation to natural rubber latex was unlikely to explain this.
- Among MRTs, respiratory symptoms were associated with workplace factors and tasks in the past 12 months likely to generate aerosol or chemical exposures.
- Examples include cleaning processor chemical spills, delayed clean up of leaking processor, clogged floor drain, and processors not having local exhaust ventilation.

Policy implications

- Radiographers represent a large sector of the workforce.
- The results suggest apparent possible benefits from avoidance of high level irritant exposures; approaches include efforts to improve work practices, clean up of leaks, and ventilation of settings in which film is developed.
- A greater emphasis in the future on alternate technologies such as digital imaging will likely lead to lower exposures.

tasks, suggests a work related aetiology. However, the mechanism remains unknown despite the presence of both irritants and sensitisers. Our preliminary findings of low percentages of eosinophils in induced sputum among MRTs[25] suggest that the mechanism may involve, at least in part, a role for respiratory irritants, and/or other non-IgE mediated mechanisms.

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Authors' affiliations

G M Liss, S M Tarlo, J Doherty, J Purdham, J Greene, Gage Occupational and Environmental Health Unit, University of Toronto, Canada
L McCaskell, Ontario Public Service Employees Union
M Kerr, Institute for Work & Health

APPENDIX 1: RESPIRATORY QUESTIONS FROM VENABLES AND COLLEAGUES[18]

(1) When you have run or climbed stairs fast, have you:
- coughed?
- wheezed?
- got tightness in the chest?

(2) Has your sleep been broken by:
- wheeze?
- difficulty in breathing?

(3) Have you woken up in the morning with:
- wheeze?
- difficulty in breathing?

(4) Have you wheezed:
- when you were in a smoky room?
- when you were in a very dusty place?

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