

Review Article

Risks and health effects in operating room personnel

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Abstract. *Objective:* The objective was to find the factors that pose a possible health risk to OR personnel. Work-related health problems of operating room (OR) personnel were signalled by an occupational physician and preparations for the development of new Worker's Health Surveillance (WHS) were started with a systematic review of the literature.

Methods: A systematic review was performed of articles in Pubmed, published from January 1991 to December 2007, concerning risks or health effects in the working conditions of OR personnel.

Results: Twenty-three articles reported that workers in the OR are exposed to infectious agents, noise, anaesthetic gases and radiation. Eleven studies reported elevated risk for (allergic) skin diseases, musculoskeletal complaints and infectious diseases.

Conclusions: Factors that form a health risk for workers in the operating room are infectious agents, noise, anaesthetic gases and radiation. Health effects on workers in the OR are (allergic) skin disorders, musculoskeletal complaints and infectious diseases.

Keywords: Workers health surveillance, working conditions, exposure, infection, allergy

1. Introduction

Every four years, Dutch employers have to provide a workers' health surveillance (WHS) report to their personnel, based upon the risks in the working environment, as delineated by general legislation. This WHS is voluntary, except in situations for which the law requires it; for example, for jobs where the safety and health of the public is at stake as well. Some years ago it seemed that there were many thyroid diseases in a group of workers in the operating room of one hospital in the Netherlands. The need for an investigation by a WHS seemed obvious to the occupational physician (MvdB). Because there was no evidence based guide-

line on what health effects and risks should be investigated in workers in an operating room, a literature study was performed. The question was: what health related factors pose a possible health risk in the work of OR personnel?

2. Method

A search was conducted in Pubmed including studies from January 1991 to December 2007. Only studies in English, German and Dutch were included. Equivalents of the phrases operating room and operating room personnel, including all the names of the workers in the operating room, were combined with the term health risk, to find all possible relevant articles (search information is available from the authors).

Studies were selected by MvdB on the basis of title and abstract. The studies had to meet the following inclusion criteria: (1) operating room personnel had

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to be the subjects of the study and one of the two following had to be true: (2) a health effect or a risk for the workers in the OR had to be described or (3) the relationship between the health effect or risk and the working conditions were the subjects of the study. In case of doubt a decision was made after a discussion between the three authors.

The full texts of the included articles were reviewed. The following items were described: (1) the design of the study, (2) the description of the participants, (3) the description of a control group, (4) the type of risk or health effect, (5) the outcome measures and (6) the results. All the selected studies were discussed by the three authors. The articles read were classified by the kind of risk or health effect and presented as such.

3. Results

The first electronic search resulted in 1025 potentially appropriate articles. Based on title and/or abstract, most of the articles were excluded because they did not meet inclusion criteria as they dealt with patient care instead of OR personnel. Other reasons for exclusions were the articles 1) discussed the management of a risk, 2) dealt with the economical consequences of a risk, 3) was a personal view on a topic, 4) appeared to be a guideline or 5) described risks for health care workers in general instead of workers in the operating room. On the basis of title and abstract 56 articles seemed to be appropriate. Reviewing the full text and considering the inclusion criteria, 34 articles met the required conditions. Of these, 23 dealt with some kind of exposure and 11 with some kind of effect on health. The studies on exposure are described below (see Table 1), and then followed by the studies on the health effects (see Table 2).

3.1. Infectious agents

Fourteen studies dealt with infectious diseases as possible health effect. Exposure was caused by splashes and percutaneous penetration [1–4]. The operating rooms of the cardiothoracic, trauma and obstetric caesarean departments had the highest exposure risk [5]. The most commonly affected contact site was the fingers and the most commonly affected member of the team was the surgeon [6,7]. Perforated gloves, needle stick injuries, aerosols, and bone marrow and long lasting operations appeared to be additional sources of exposure to infectious diseases [7–13].

3.2. Noise

Two studies investigated noise in the operating room. In these studies it was found that there was no risk for hearing loss in the OR during Ultrasound Assisted Liposuction or during Extracorporeal Shock Wave Lithotripsy [14,15].

3.3. Anaesthetic gases

The concentration of anaesthetic gases in the OR was higher for the surgeon than for the anaesthetist, but revealed no increased risk for reproductive disorders, except under abnormal conditions (e.g., an uncuffed endotracheal tube, tubing flushing or a fitting disconnection between the anaesthetic machine and the hospital venting system) [16–18].

3.4. Radiation

Radiation induced diseases have been described in connection to working in the operating room. The mean exposure to radiation during percutaneous nephrolithotomy was considered safe by the International Commission of Radiological Protection [19]. The mean dose of radiation in cardiac procedures was about 0.05 mGy [20]. In refractive surgery, scattered UV radiation had a maximum of 80 nJ/pulse [21]. The annual morbidity risk associated with thyroid radiation was 0.025% in spine surgery during fluoroscopically guided procedures, representing a low to medium risk. The life-time morbidity risk associated with thyroid radiation was high to very high for operators in the OR [22].

3.5. Skin disorders

Allergic skin disorders can be a health effect resulting from wearing latex gloves during work. The prevalence of allergy to natural rubber latex in operating room personnel varied from 1–14% [23–26]. The prevalence of adverse reactions to latex gloves varied from 41–55% [25,27,28].

3.6. Musculoskeletal complaints

The prevalence rate of lower back pain complaints during the last 12 months in operating room nurses varied from 58–77% [29,30].

3.7. Infectious diseases

Regarding infectious diseases, 23% of the surgeons in Denmark had serological evidence of previous HBV infection [31]. Of these, 39% recalled an episode of clinical viral hepatitis. Surgeons in the operating room were more likely than other professionals, for example scrub nurses, to be influenced in their choice of protective clothing (e.g., eye protection, double gloving, covering cuts with waterproof dressings) by known patient infection [32]. It appeared that the relative risk of occupational HIV seroconversion is 15 times higher in Africa than in Western countries [33].

4. Discussion

This paper shows that the effects on workers in the operating room can be: skin disorders, infectious diseases and musculoskeletal complaints. Also, it is clear that these workers are exposed to anaesthetic gases, noise, radiation and infectious agents. This information can be used to set up a WHS. A WHS is meant to prevent occupational diseases and work related disorders in individual workers or in groups. Its purpose is also to guard and promote the health of workers in relation to their job. A WHS for operating room personnel should therefore pay attention to complaints of the locomotory system, especially lower back pain and arm/shoulder pain, and to complaints of the skin, especially of the hands. Also, the exposure to radiation (dosimeters, the function of the thyroid), infectious agents (vaccination), anaesthetic gases (reproduction disorders) and noise should be monitored in a WHS. Surgeons, their assistants, operating room nurses, anaesthetists, technicians in the OR, midwives and students in these jobs are eligible for a WHS. Presumably, this type of WHS should be repeated every 2 to 4 years, depending on the results and age of the workers in the OR. Workers who report striking complaints should be invited for a physical examination by the occupational physician.

The strength of the study is the fact that the risks and health effects on workers in the OR are clearly brought together. A weakness may be the general search strategy that was used in terms of 'health risk' without the specific inclusion of text words representing specific exposure parameters. Because of this a-priori choice otherwise relevant articles may have been missed (e.g. [34]).

Several papers concerning infectious agents described that the operators were not sufficiently aware of

the risks in their occupational environment. For example, they did not know how many splashes were found on their goggles, that more than 20% of the gloves used in major operations were perforated or that after 5 years of study almost 100% of the medical students had a sharps injury or needle stick injury. The fact that some surgeons, more than other professionals, are not so careful in their choice of clothing (e.g., eye protection, double gloving) in light of known patient infection may lead to unnecessary exposures in the OR. The provision of clear information can possibly play a role in the prevention of occupational diseases, as part of a WHS.

In his study, Harstall [22] made clear that although the annual morbidity associated with thyroid radiation is 0.025% per unit, the life-time risk is high to very high for operators. Although collar shields are sometimes worn by operating room personnel, this is not always common use.

This study was not directed at recovery room personnel. The same risk factors as found in the OR may be present in the recovery room as well, whereas fewer preventive measures may be available or taken there. Patients exhale anaesthetic gases in the recovery room, but the ventilation is possibly not given as much attention as in the OR. In addition, X-rays as an example of radiation exposure, are taken there too, while the environment is often not suited to that purpose. Further research that focuses on the risks for the recovery room personnel seems important as well.

5. Key points

- Operating room personnel are still exposed to infectious agents, noise, anaesthetic gases and radiation during their work.
- Known health effects in operating room personnel are: (allergic) skin diseases, infectious diseases and musculoskeletal complaints.
- A Workers' Health Surveillance for operating room personnel should include self-reports investigating complaints of common health, of the skin, the musculoskeletal system and reproduction. Attention must also be paid to the prevention of infectious diseases (vaccination), radiation (lead shielding), and noise.

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Appendices

Table 1
Studies that report on exposures in the OR

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Kraig S. et al. 2005 USA	Survey Risk/hazard analysis	Refractive surgeons (number/age/sex unknown)	No	Hazard/risk of scattered UV laser radiation and broadband UV plasma emissions during refractive surgery.	UV measurements (in nJ/pulse), the distance from the laser (in cm) and the angle from the axis of the laser, during calibration, PRK and Lasik	Maximum measured values of 80 nJ/pulse at 14 cm for PRK (Photorefractive keratectomy) and 45 nJ/pulse at 38 cm for Lasik (Laser in situ keratomileusis). UV scattered Radiation level was similar between PRK and Lasik
Kumari G. 2006 India	A prospective cohort		No	Exposure to radiation during percutaneous nephrolithotomy (PCNL)	The radiation dose to various operating room personnel during 50 consecutive PCNL procedures. The International Commission of Radiological Protection: extremities of radiation workers receive up to 500 mSv in a year	Mean exposure to the finger of the urologist was 0.28 mSv (SD ± 0.13 ; range 0.02–0.57 mSv) and that to the assisting resident was 0.36 mSv (SD ± 0.50 ; range 0.06–2.21 mSv) Mean radiation dose at trunk level in μ Sv Urologist 24.9 Assisting resident 12 Technical assistant 2.6 Anaesthetist 1.7 Radiographer 1.7 Scrub nurse 0.3 Floor nurse 0.16
Zorzetto M. 1997 Italy	A prospective cohort	Unknown how many cardiologists, nurses and radiographers during 58 cardiac procedures (sex and age unknown), from March to June 1995	No	Exposure to radiation	The distribution of the values of dose per procedure at collar level	The mean dose per procedure was about 0.05 mGy for the cardiologist Nurses and technicians received smaller doses. Only 15% was above the detectable level (0.015 mGy)
Barbosa M.V.J. 2004, Brazil	Cohort study, prospective	Group A: 390 gloves from 100 consecutive minor plastic surgery procedures used by 1 surgeon and 1 assistant. Group B: 710 gloves from 100 major plastic surgeries, used by 1 surgeon and 3 or 2 or 1 assistants	No	Glove perforation in minor and major plastic surgery procedures.	The minor procedures required 10–30 minutes, the major procedures required 1–6 hours. Perforation of the gloves was detected by overfilling them with water and squeezing each finger (Maffuli's test) A perforation index was created. P = the number of first assistant glove perforation divided by the total surgical time (min) The outcome measures were: number of procedures, number of gloves used, total number of glove perforation, team member (surgeon, 1st assistant) average time of the procedure, perforation index, perforation in left or right glove	4 gloves (1.02%) in 3 minor procedures were perforated as compared with 76 gloves (21.4%) from 49 major procedures. A statistically significant difference ($p < 0.0001$, chi-square test with Yates' correction). No perforations were found in the gloves used by the surgeon for minor procedures. A statistical difference was found in the incidence of first assistant glove perforation between minor procedures (4 gloves) and major procedures (31 gloves). Surgeons (59.21%) were more likely to be injured than their first assistant (40.79%) during major surgery, but the difference was not statistically significant. The left glove was the most frequently perforated in both groups A: 75% and B: 78.94% Average time of procedure in group A was 17.55 min., group B 186 min. The perforation index for the first assistant's glove showed one perforation every 417 min for group A and one perforation every 600 min for group B. No significant difference was observed when these values were compared. There was no statistically

Table 1, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Hentz V.R. 2001 USA	A prospective cohort design	(97) Surgeons in 3 medical centres: Stanford, USA Ferrara, Italy Carpi, Italy	No	Glove barrier failure	An electronic device was designed to alert the participants of wet contacts between surgical staff and patient. The device sounds an alarm 1) on perforation of a glove, 2) when the latex gloves become hydrated, 3) when there is a direct wet contact, due to soaking of the sleeve or gown Outcome measures: – surgical procedures – reasons for alarm by the device – alarms per centre – Incidence of glove perforations – Location of the perforation site	significant difference in the perforation index between the minor and major procedures. 111 surgical procedures were monitored; 67 microsurgeries, 22 orthopaedic surgeries, 22 general surgeries. Of the 278 alarms, 44 (15.8%) were associated with glove perforation, 39 (88.6%) of which were not perceived by the operator. 76 (27.3 %) was due to sleeve/gown wetting, and 121 (43.5%) due to glove hydration. 37/278 (13.4%) appeared false positive. 22 of the 23 perforations in microsurgery happened single-gloved, only one double-gloved. In orthopaedic surgery 2/11 perforations happened single-gloved, and 9/11 double gloved
Makary M.A. 2007, USA	A cross-sectional survey	702 surgeons in training, 31% women	No	The prevalence of needle stick injuries	Needle stick injuries according to postgraduate year (PGY) The response rate was 95% PGY1: 64% had needle stick injuries PGY2: 89% PGY3: 94% PGY4: 91% PGY5: 99%	
Byhahn C. 1999 Germany	Prospective cohort study	Personnel in the operating room, recovery room, children's department en bronchoscopy room and intensive care of the Frankfurt University Medical Centre, Germany. They were exposed in 345 procedures under general anaesthesia.	No	Exposure to nitrous oxide (laughing gas), desflurane and sevoflurane	Place of measurements, type of anaesthetic agent, concentration in the breathing zone of the personnel, air-conditioning in the work space, duration of measurement, exposure of the personnel to the anaesthetics in the different work spaces, Agent-index (in Duits: Stoffindex) = mean exposure in a working time of 8 hours divided by MAC The threshold of the agent-index is 0,1	The agent-index of nitrous oxide for the anaesthetist in the operation rooms varied from 0.001 to 0.005, whereas the index for the surgeon or the health care workers on the ICU was 0.141, and 0.101 in the recovery room.
Byhahn C. 1999 Germany	Cohort study	The procedures were performed by an ophthalmologist and an anaesthesiologist.	No	Exposure to nitrous oxide and desflurane during eye-surgery	During the whole operation, every 90 seconds a sample of air in the breathing zone of both surgeon and anaesthesiologist was measured for presence of Desflurane and laughing gas	The mean concentration of Desflurane for the eye surgeon was 2.80 ppm and for the anaesthesiologist 0.43 ppm. The mean concentration of Laughing gas for the eye surgeon was 11.60 and for the anaesthesiologist 2.80 ppm. The MAC in Germany at that moment was 100 ppm.

Table 1, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Li S.H. et al. 2001 Taiwan	A prospective cohort	The anaesthetic staff of the Armed Forces Taoyuan General Hospital (number unknown, sex unknown)	No	Exposure to the anaesthetic gases: nitrous oxide and enflurane (SEV)	Concentration of N ₂ O and SEV during 5 surgeries The US-Niosh recommends a time weighted average (TWA) of 25 ppm (part per million) for N ₂ O and a ceiling of 2 ppm for SEV.	The average N ₂ O concentration was 31.5 ppm. The peak value for SEV was 1.45, so less than the ceiling of 2 ppm. 3 abnormal conditions resulted in exceptionally high concentrations: Tubing flushing: N ₂ O 751 ppm and SEV 26 ppm Uncuffed endotracheal tube: N ₂ O 603 ppm and SEV 32.7 ppm Fitting disconnection between the anaesthetic machine and the hospital venting system: Up to 100 ppm for N ₂ O and up to 6 for SEV.
Nogler M. et al. 2001 Austria	Quasi-Experimental	Surgical team: 1 surgeon 1 anaesthesiologist 1 assistant 1 scrub nurse (age and sex unknown)	No	Risk of contamination by Staph Aureus of aerosols, using high-speed cutters in cervical spine surgery on body	Extension of aerosols in the operating room and the individual exposure to Staph Aureus	100 CFU (colony forming units) were found on the surgeon and the assistant, the whole team showed contamination of their faces and bodies. All Petri dishes in the studied area of 5 × 7 m, showed growth of staph aureus from 10- 100 CFU per plate for air sampling.
McNamee I.R. et al. 2006 UK	Study1: Survey Study2: Observational case-study	Study1: Consultants and junior plastic surgeons Study2: one single surgeon and 129 patients	Study1: no Study2: no	Study1 + 2: transconjunctival virus transmission	Study 1: – frequency of wearing goggles or other eyewear – estimated frequency of splashes – diseases thought to be transmitted – frequency of eyewear for high risk patient Study 2: The frequency of lens splashes during 143 procedures	Study1: 36 respondents (response rate of 84%), all grades recognised the risk but most respondents did not wear goggles. Respondents changed their behaviour in high risk cases. Study2: 143 procedures resulted in 42 splashes. The surgeon was only aware of the splash in 6 cases.
Altat A. et al. 1998 Pakistan	Case study Method is contact tracing	Exposed family members of a nomadic shepherd, all his hospital contacts and the contacts of 3 secondary cases (2 surgeons and a theatre assistant) 3 relatives of the family of the shepherd	No	Contamination by Crimean-Congo haemorrhagic fever	Exposure, classified in 5 categories, and serological status, presence of IgG and IgM, of contacts of the shepherd. Information about the exposure was gathered by interview. Information about the immunoglobulin antibodies by blood samples tested by ELISA	The family of the shepherd refused to give blood and declined individual interviews. The families of the secondary cases (10), the secondary cases themselves (3), and 40 of 42 HCW's were interviewed and gave blood. 2 out of 4 people were exposed percutaneously and 1 out of 5 with cutaneous exposure contracted CCHF. The person with cutaneous exposure was a surgeon who tore his glove during surgery and noted blood on his hand, but no cut. There were no anti-CCHF antibodies or CCHF cases among persons whose skin came into contact with body fluids other than blood (0/4), who had skin to skin contact (0/16) with patients or were physically close to them (0/21). 3 relatives of the shepherd reported that although 10 family members had cutaneous exposure, none developed CCHF.

Table 1, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Chandler R.E. 2006 USA	Case report.	A subgroup of 37 health-care workers in the operating room (Age/sex unknown)	No	Contamination by Group A Streptococcus (GAS)	- duration of exposure - direct contact with the wound - rapid streptococcal antigen testing	22/37 had direct contact with the patient. 13/22 reported exposure to the patient > 1 hour. 15/22 reported touching the open wound of the patient. 9/22 were exposed > 1 hour and had contact with the wound. 2/9 became infected.
Regez R.M. 2005 The Netherlands	A prospective cohort (5 patients)	5 HIV-infected patients undergoing surgery in OLVG (Sex and age unknown)	No	Exposure to (the HIV-1 viral load of) bone marrow	-HIV-1 RNA viral load in copies/mL in blood and bone marrow	The viral load measured in plasma was not different from the viral load in bone marrow at the time of surgery. The concentrations were at or below the detection limit in all patients.
Dement J.M. 2004 USA	A prospective cohort study	24,425 Health care Workers employed by Duke University Health System	No	Blood and Body Fluid (BBF) exposure	Employee level demographic information: gender, race, job code, work location, hours worked per week. Exposure events: type of exposure, job title, work location and calendar year Exposure rates (events/100FTE)	Total BBF events analysed 1998–2002: 2730. Percutaneous exposure was the predominant type; 72.1%. 31.1% of the BBF events occurred in the operating field. Overall annual BBF exposure rate is 5.5 events/100FTE's In the occupational groups, the Surgical-operating room technicians are noteworthy: 51 exposures took place by 117 FTE's The exposure rate is 43.7 Exposure rate of nurse anaesthetists is 12.6 (32/254)
Popejoy S.L. 1991 USA	A prospective cohort	Workers in the operating room at the University of New Mexico Hospital from 15/2/1988 to 15/3/1988 during 684 surgical procedures. (Sex and age unknown)	No	The exposure to blood	- blood contact events - blood exposure events Blood contact was defined as percutaneous, mucous membrane, nonintact skin or intact skin contact with patient blood. Blood exposure was defined as contact in any of the preceding categories excluding intact skin.	190/684 procedures (28%) resulted in blood contact. 3 services, Ophthalmology, Transplant and Oral surgery, reported no blood contact. 3 services had significantly higher exposure rates compared to all other services: Cardiothoracic (58%, $p = 0.001$) Trauma (49%, $p = 0.003$) Obstetric caesarean section (48%, $p = 0.021$). 54/684 procedures (8%) resulted in blood exposure. Cardiothoracic surgical treatment was the only service with a significantly greater rate of exposure when compared with other services ($p = 0.04$)
Taylor J.D. 1990 Australia	A prospective cohort	1 urologist (sex and age unknown)	No	Exposure to blood at transurethral resection	The pattern of blood contamination of the surgeon's face, revealed by a fluorescein marker technique	Two patterns: - 13/20 operations there was a random distribution of splashes. - In only 3 instances the splashes were visible to the naked eye - 17/20 operations the pattern involved the left eye and the tip of the nose. In only 4 occasions this was visible to the naked eye. (The surgeon resects using the right hand while looking through the telescope with the left eye)

Table 1, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
White M.C. 1993 USA	A prospective cohort	Operating room personnel in 9 American hospitals, age and sex unknown.	No	Exposure to blood	- job classification by type of blood contact - location of blood contact - activity at the time of blood contact	In 864/8502 surgeries (10.2%) HCWs had blood contact. 1054 persons had blood contact. - Nearly 21% of blood contacts among surgeons were pariental as compared with 11% among nonsurgeons. - The most common contact sites were the fingers (42.5%). Hands, fingers and arms accounted for 59.4%. The face and neck accounted for 24.2% - surgeons and scrub assistants accounted for 73.2% of all contacts - activities: For parenteral exposures, suturing accounted for 36.2% and activities related to surgical cutting accounted for an additional 27% of the blood contacts. 46.9% of exposures to intact skin were from unknown sources (surprise spatters etc)
Wong D.A. 1998 USA	A retrospective cohort, as part of a bigger study in '92-'93	2234 HCWs in 324 spine surgery procedures in Denver, Colorado (age and sex unknown)	No	Exposure to blood	- Contamination rates by surgical department - contamination of HCW by member of the surgical team - aetiology and cause of contaminated cases.	- Total contamination rates for spine surgery (31.86%) were statistically higher ($p < 0.05$) than the rates for the overall study (7.76%). - Surgeons were the most commonly contaminated team members in spine surgery, followed by the first assistant, scrub nurse, circulating nurse and anaesthesiologists. The distribution was similar to that of total contamination data in the multi department series. - In the spine surgery group, contamination occurred most commonly while using an instrument, as opposed to the overall series in which contamination was most commonly associated with instruments lying in the field. In spine surgery, contamination most commonly involved the hands and the face.
Askew S.M. 2007 USA	A retrospective survey	28,506 medical students, health profession students, nursing students and dental students at 3 medical schools in Virginia. (Sex and age unknown)	No	Exposure to blood	Rate of blood and body exposures among students	From 2001 to 2005, 519 exposures to blood-borne pathogens were reported. Average rate: 2.26% (rate of exposure per 100 students) The average health care student experienced most exposures in the operating room (49%) At one of the schools, surgical assistant students reported 32 exposures from 2001 to 2005: 90.6% were needle stick and sharps injuries and 9.4% were blood and body fluid exposures. 71% reported that their injury occurred in the OR. 60% reported that they were not the original user of the device causing their injury.

Table 1, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Kenkel J.M. 2000 USA	A prospective cohort	1 (or more?) plastic surgeons, 18 patients (sex and age unknown)	No	Risk of hearing-loss during ultrasound-assisted liposuction	– Sound intensity at 3 sites 1) surgeons' ear 2) at surgical site 3) at patient's glabella 6 measurements using Mentor Contour genesis system. 6 measurements using Lysonix 2000 system 6 measurements during traditional liposuction Hearing loss can occur after an acoustic trauma, (>140 dB, short duration, high intensity) or by intensity > 90 dB, during prolonged periods.	Mentorsystem: (averaged) At surgeon's ear: 67dB, or 73 dB At surgical site: 76 dB or 81 dB At patient's glabella: 60 or 63 dB The second figure is a measurement when an external sheath system is added Lysonix: (averaged) At surgeon's ear: 72 dB At surgical site: 88 dB At patient's glabella: 64 dB Sound intensity exceeded 90 dB only once, at the surgical site Traditional lipectomy: At the surgeon's ear: 60 dB At surgical site: 63 dB At patient's glabella: 59 The 2 used systems pose no risk of hearing loss.
Terlecki R.P. 2007 USA	A prospective cohort	5 patients undergoing Extracorporeal Shock Wave Lithotripsy (ESWL), 1 ESWL technician, 1 urologist, and 1 anaesthetist (sex and age unknown)	No	Risk of hearing-loss during ESWL	5 sound level measurements during each treatment session at the next locations: 1) patient's head 2) technician's station 3) anaesthetist's station 4) urologist's station 5) There was also a baseline measurement without ESWL in the OR	Average sound level Range (dB) 1) 89 dB 88–90 2) 84 dB 82–85 3) 81 dB 80–81 4) 79 dB 78–80 5) 62 dB 61–63 The OSHA standards permit 8 hours of exposure to 90dB per day. So each station can be considered as safe. OSHA = Occupational Safety and Health Administration
Harstall R. 2005 Switzerland	A prospective case control study	2 spine surgeons (Age and sex unknown) performing 32 vertebroplasty procedures	No	Radiation exposure to the thyroid gland	Radiation dose was measured on 6 places of the body of the surgeon, under the site of the thyroid	The cumulative radiation dose on the thyroid gland position was 7.1 mSv. The extrapolated value for the annual thyroid radiation dose was 31.2 mSv

Table 2
Studies that report on health effects in the OR

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Hardt F. 1979 Denmark	A cross-sectional survey	224 surgeons who were participants of the annual meeting of the Danish Society of Surgeons in 1977	Control population: 960 voluntary blood donors and 935 unselected hospitalized patients.	The prevalence of HBV infection	Serum samples were examined for HBsAg and anti-HBs, and a questionnaire was given with items: – age – years of experience – major field of surgery – previous hepatitis – known source of infection	0/224 had circulating HBsAg and 51/224 (23%) had anti-HBs 25% performed general surgery, 37% parenchymal surgery, 20% orthopaedic surgery. All three groups had the same prevalence of anti-HBs The overall prevalence of anti-HBs in surgeons is significantly higher than that in blood donors and hospitalized patients ($p < 0.05$), and it rose at a significantly higher rate with age than that in the blood donors and hospitalized patients when regression lines were tested with an F-test for variance. Of the 19 surgeons positive for anti-HBs and previous known hepatitis, 14 had required hepatitis when working in surgical departments in contrast to 12 of the 18 anti-HBs negative surgeons, who acquired hepatitis before entering the surgical profession. ($p < 0.05$) Only 19 (39%) of the 51 surgeons with serological evidence of previous HBV infection recalled an episode of clinical viral hepatitis. The response rate was 70%. 23 persons (14.1%) had specific IgE antibodies against Latex. RAST test 17/23 (73.9%) had also positive skin tests for inhalation allergens, while 40% (56/140) had so without having a pos skin test for Latex Persons with an atopic constitution ran an increased risk of Latex sensitization (odds ratio 4.3, 95% CI 1.6–11.4) Of these 23 persons, 16 showed symptoms of urticaria, angio-oedema rhinoconjunctivitis and/or dyspnoea. The prevalence in OR-personnel is 23/163 = 14.1%
Bijl A.M.H. 2008 Holland	A prospective cohort study	163 persons working in the ORs of the academic hospital of Rotterdam, 30 men, 133 women, mean age 38 years (range 18–60)	No	The prevalence of allergy to natural rubber Latex	A questionnaire, blood samples and skin tests were performed	Only 1 of the 102 persons had a positive RAST test. He stated he was asthmatic but not atopic, he was not allergic to fruit, had no surgery. His symptoms were skin irritation erythema, urticaria and wheeziness. 32/102 experienced local hand symptoms There was no clinically significant change in daily FEV ₁ /FVC Conclusion: In this study the prevalence of Latex allergy in operating theatre staff is 1% (1/102)
Hack M.E. 2001 Australia	A prospective cohort study	102 persons working in the OR, 33 males, 69 females, average age 34.4 years	No	The prevalence of allergy to natural rubber Latex	A questionnaire, spirometry and IgE determination in blood samples	Response rate was 68.4% (210/307) The prevalence of adverse reactions to Latex glove was 41.4% (87/210): itching rash dermatitis, urticaria, dyspnoea, dizziness, wheezing
Hwang J. 2002 Korea	A cross-sectional survey	307 hospital personnel (243 surgical residents, 64 operating room nurses) 210 respondents: 138 males, 72 females)	No	The prevalence of the adverse reactions to Latex glove use	A questionnaire	

Table 2, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Korniewicz D.M. 2005 USA	A retrospective cohort	All operating room personnel were asked to participate ($n = 300$) but 103 people were enrolled in the study. Their average age was 35.9 years, 58 males, 45 females	No	Exposure to latex, during a conversion from powdered to non-powdered gloves	A questionnaire and a RAST test	Response rate was 34% (103/300) 42% reported symptoms with NRL exposure prior to the conversion Only 60 participants completed RAST testing 3/60 (5%) had NRL-specific IgE After conversion to non-powdered NRL gloves there was a significant decrease in reported symptoms: 29%
Mace S.R. 1998 Canada	A prospective study	247 operating room nurses, recruited at an annual meeting of their professional association. Mean age 44.2 years (SD=+8) Sex unknown	No	Prevalence of latex allergy in operating room nurses	- A questionnaire with natural rubber related questions - Skin Prick Testing - ELISA test for the subjects with a positive skin prick test	- 54.7% (135/247) recorded symptoms attributed to latex exposure. 17 subjects had a positive skin prick test, 9/17 (52.9%) had a history of atopy. - 3/17 (17.6%) gave no history of reactivity to latex. - 230 had a negative Skin prick test. 35/230 (15.2%) had a history of atopy. Latex ELISA for IgE was positive in 12/17 (70.6%) The prevalence in this group is 17/247 = 6.9%
Sener O. 2000 Turkey	A prospective cohort	Group 1: 206 health care workers: 131 residents from various surgery branches, 13 dentists, 28 operating room nurses, 26 surgery technicians, 8 medical assistants, 171 males, 35 females, mean age 30.6 years Group 2: 100 atopic patients, 61 males, 39 females, mean age 28.8 Group 3: 100 nonatopic patients, 39 males, 61 females, mean age 35.3	Yes	Prevalence of latex allergy (exposure?)	- a questionnaire - Skin prick tests = SPT - Patch test with 3 rubber additives were performed in the latex skin prick test positive cases	- 19/206 had a positive SPT (9.22%), nobody from the two control groups had a positive SPT. - 2/19 (10.5%) had delayed type hypersensitivity to rubber additives The healthcare workers were divided in 2 groups: SPT+ and SPT-. Daily exposure time (68%) and the number of operation gloves used per day (73%) were significantly higher in the latex SPT+ group. The positive history of allergic rhinitis (42%), bronchial asthma (15%), and conjunctivitis (36%) were significantly higher in the latex SPT+ group The prevalence of latex allergy is 9.22%
Bos E. 2007. The Netherlands	Cross-sectional survey	3,169 employees of 8 university hospitals in Holland, among them 381 operating room nurses, 85% females mean age 40 (SD 8)	No	Musculoskeletal complaints of neck-shoulder and low back	- Person-bound variables like age and years of employment. - prevalence rate of musculoskeletal complaints. - Physical and psychosocial risk factors like: Dynamic load, static load, job content, job demands.	Prevalence rate of lower back complaints (the last 12 months) in operating room nurses is 76.6%. For neck-shoulder complaints it is 69.4% which is more frequent compared to non-specialised nurses ($p < 0.01$) and IC-nurses ($p < 0.01$). In operating room nurses no relationship emerged between risk factors and complaints (surprising finding!)

Table 2, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Meijssen P. 2007 The Netherlands	A cross-sectional survey	463 (student) operation assistants, 85.1% women. The mean age was 36 (SD= 10.3)	No	The prevalence of Musculoskeletal disorders (MSD)	Back pain in the preceding 12 months. Back pain in the preceding 3 months. Other MSD during the preceding 3 months.	The response rate was 75%. The 12-month prevalence for back pain among operation assistants is 58%. That is significantly higher than in the general population in the Netherlands (40–43%). The 3-month back pain prevalence is 46%. Other MSD's: Headaches 48% Neck/shoulder 53% Pain in arms/hands 14% Pain in legs/ feet 43% Pain in the knees 22%
Consten E.C. 1995 Holland	A prospective cohort study	7 surgeons and their personnel, 1078 patients (579 men, 499 women) in a hospital in Zambia	No	The relative risk of occupational HIV transmission in Africa	HIV seroprevalence among the patients, incidence of occupational parenteral exposures, dexterity of the staff and years of experience. The procedures were categorized in 5 groups: general, orthopaedic, urologic, gyn/obst, ophthalmologic surgery. The cumulated risk of seroconversion due to parenteral blood exposure can be calculated as: $1 - (1-p)^{ny}$, where f is the population seroprevalence, p the chance of transmission per incident, estimated to be 0.46, n the number of parenteral exposures per year and y the years of practice	A randomised sample of 305 out of 1078 serum samples (of the patients) was tested in the Netherlands. 66/296 (22.3%) were seropositive, 9 undetermined. Between the surgical specialties no significant difference existed in seroprevalence. During 1161 procedures 12 parenteral exposures were observed (1.0%). The non-dominant index finger was exposed in 10/12. Exposure rate was inversely related to surgical experience: seniors 4/747, juniors 4/414, not statistically significant For a surgeon working in Zambia during 5 years, the risk of contracting HIV can be calculated at 1.5%, with $f=22.3\%$ and n is 3 per year (0.7% of 400 operations). The risk for a surgeon working in a western hospital can be estimated at 0.1%. Thus the relative risk of occupational seroconversion is approximately 15 times higher in Zambia than in western countries.

Table 2, continued

Author	Design	Participants	Control group	Risk or health effect	Outcome measures	Results
Cutter J. 2004 UK	A cross-sectional survey	120 surgeons, 84 scrub nurses and 72 hospital-based midwives, employed general operating theatres and delivery suites within 1 national health service trust ($n = 276$)	No	Acquiring blood borne infections during exposure-prone procedures	Questionnaires were distributed via internal mail and reposted to non-respondents after 3 and 6 weeks. Items were: – uptake of universal precautions – impact of profession on factors affecting choice of protective clothing – causes of inoculation injuries sustained by respondents – reporting injuries – education and compliance	The response rate was 72.5% (200/276). Only 3 of 200 (1.5%) respondents would adopt all seven theatre-specific measures for all patients. – covering cuts with waterproof dressings: 173/193 – double gloved 13/178 – eye protection 88/192. The mean number of precautions was 3,725 of 7 (SD 1,385) 162/194 were influenced in their choice of clothing by knowledge of patient infection. Surgeons were more likely than other professionals to be influenced by known patient infection (80/87, 92%) compared with 40 of 50 (80%) nurses and 42 of 57 (74%) midwives. The difference was significant for the midwives ($p = 0.003$) Most respondents 145/196, 74% reported sustaining at least one inoculation injury within the 10 years prior to the study. The incidence was the highest among the surgeons (87.8%) the lowest under midwives (47.3 %). Only 98 of the 145 respondents who admitted sustaining injuries reported them (67.6%) Reason given: – Reporting mechanism too cumbersome 75% – Lack of time 55.6% – Patient not at risk 86.4% – Occupational risk 55.6%. 119/188 (63.3%) admitted making judgements based on lifestyle, sexuality, nationality, and known or suspected blood-borne infection of the patient, although 95.5% reported that education influenced their choice of protecting clothing