"Operating Room Nurses' work environment due to surgical smoke".

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In September 2015 the Swedish Operating Room Nurses Association, SEORNA, published a recommendation of prevention of surgical smoke, which is written in the Swedish language. This recommendation can be assessed from www.rfop.se . During the work with the recommendation we, the Swedish "Quality Council", has found a considerable amount of scientific and non-scientific articles about surgical smoke.

Surgical smoke is generated during surgeries when using rapid mechanical tools or heat-producing devices. What substances is it in the smoke? How small are the particles? Are the smoke dangerous for the patient and for the members of the surgical team? How long distance do the particles spread? How to prevent and protect ourselves from inhaling the smoke, get it in the eyes or on the skin? Some of the questions will be illuminated here. This is a review and updating of knowledge of surgical smoke, prevention and protection. Most likely, there are many more scientific articles written and to find, than those listed here.

First of all: What attitudes do we have when it comes to surgical smoke? Do we take the surgical smoke seriously? Do we behave properly - to protect and prevent patients, co-workers and ourselves against surgical smoke?

I have found in the literature reports of only three persons, who have suffered from tumors in relation to surgical smoke. Probably, there are many more unreported cases. Two operating room nurses and one surgeon, who have worked in the operating rooms. All three of them were young when they got the diagnosis, the surgeon was 44 y and the two nurses were 28 and 47 years. The operating room nurses have received their disease regarded as an occupational injury, but it is unclear if the surgeon's tumor was classified as an occupational injury. One of the nurses' lives in Sweden, and her situation has been described in the SEORNA Journal "Uppdukat" no 2, by Råghall in 2012, in the Swedish language.

In the survey by Steege et al. (2016) they reported that 47 % (of 4355 participants) used local exhausted ventilation (LEV)/mobile evacuation system when using laser surgery, but only 14 % used the mobile evacuation system when using electrosurgery. The researchers investigated the attitudes of using preventions against surgical smoke. The reasons for not using evacuation systems were for example: "not part of our protocol", "exposure was minimal", "not provided by employer". In the conclusion Steege et al. (2016) emphasized that operating procedure standards should include recommendations from industry, standard setting, and governmental organizations, and these health and safety procedures would protect healthcare personnel from exposure of surgical smoke. Lindsay et al. (2015) mean it requires strong leadership for implementation of guidelines for prevention of surgical smoke.

Medical Technical Equipment

During almost all surgical procedures we use equipment that are heat-producing in the patients' tissue. These devices uses for dissection or hemostasis, to divide tissue and for coagulate minor bleedings quickly. These medical technical equipment is necessary and serve important

functions for example by preventing that bleeding occur, to coagulate bleeding, to allow more visibility in the surgical field, shortened of the procedure-time. The benefits of these devices offers more efficient surgical techniques and they allow surgery within various surgical risk-areas. (Dåvöj et al., 2012; Jacobson & Öberg, 2003; Rothrock, 2011).
When using rapid mechanical devices and heat-producing devices smoke is generated. Surgical smoke, which are combustion gases, are formed during heat-producing energy and are generated for example when using monopolar and bipolar diathermy, laser surgery, dissection with argon gas, ultrasound, saws, drills, cutters and mechanical morcellator etc. (Ball, 2010; Ulmer, 2008; Watson, 2010).

Surgical smoke
The amount of smoke generated during surgery are depending on which medical technical equipment is used. Factors affecting the distance and the contents of the smoke depends on the choice of surgery; laparotomy or laparoscopy, the patients' age and BMI, pathology, the surgical technique, power setting, active electrode size and material of the tip/blade/pin, and exposure time during the procedure (Steege et al., 2016; Ulmer, 2008; Watson, 2010; Wu, 2011).
The surgical smoke contains 95 % water vapor and 5 % combustion products (Ulmer, 2008). Surgical smoke is described in the literature as a gaseous by-product resulting from energy-based instruments, rapid mechanical devices or heat-producing devices used in tissue. These gaseous by-products contains bio aerosols with both viable and non-viable cellular material. By-products of ultrasonic devices usually describes as aerosols or steam. The surgical smoke caused by electrosurgery and laser have the same underlying mechanisms. When cutting/vaporization, coagulation/fulguration of the tissue, the cells are heated to boiling point, leading to rupture of cell membranes and ultrafine particles (UFP) dispersed in the air or pneumoperitoneum. Dissection with ultrasound generates aerosols without heating and describes as evaporation at low temperature. These aerosols arising on low temperature are more likely to contain viable and infectious carrying particles compared to particles generated at higher temperature (Alp et al., 2006; Mowbray et al., 2013).

Some of the most common medical technical equipment in the operating rooms:
Diathermy
Smoke when using diathermy, high frequency electrical current, available in both monopolar and bipolar electrocautery. Monopolar electrosurgery can be used for cutting/coagulation or also called as vaporization/fulguration. Cutting/ vaporization has a waveform of continuous current, causes the tissue boils at 100^0 C, which makes the cell walls to explode and releases the cell liquids as vapor and spread as smoke. Coagulation/fulguration has an interrupted waveform, which causes a more gradual increase of the temperature in the cell fluid. When the temperature rises above 90^0 C to evaporate the cell liquid and over 200^0 C the tissue is carbonized (Jacobson & Öberg, 2003; Ulmer, 2008). Wang et al. (2015) reported that the first seconds, when using diathermy or laser, are those that generate high levels of UFP and thus contains many hazardous substances.

Laser
In use of laser in surgical procedures, high temperatures arises in the tissue from 100^0 C to 1000^0 C, allowing the cell liquids to boil and explode (Jacobson & Öberg, 2003; Ulmer, 2008). Smoke formed by laser contains of particles and vapors. Chemicals identified in laser smoke are benzene, formaldehyde, carbon monoxide and hydrogen cyanide. Viable particles have been found in the smoke which is a potential risk for infection. HIV-DNA and bovine papilloma virus DNA has been detected in the laser aerosols (Hallmo & Naess, 1991).

Ultrasonic

The ultrasonic dissection removes tissue with rapid mechanical friction with a low temperature in the tissue, which creates aerosols (Ulmer, 2008). Large quantities of cellular material are found in surgical smoke produced by ultrasonic dissection. In et al. (2015) demonstrated in vivo experiments, the smoke from ultrasonic dissection contained living cells which proliferated in culture medium and in the continuance of the experiment, the grown cells were injected in the tissues of laboratory mice which gave tumors to more than half of them (12/20 mice) within two weeks. Alp et al. emphasizes that the risk of inhaling more viable cells by the aerosols are greater, because they are generated under low temperature and thus are potentially more viable (Alp et al., 2006).

Electrical high-speed devices

Saws, drills, etc. are included into these, which become hot during use. These devices are cooled down with flushing of cold sterile fluid to reduce the temperature of the tissue, and this in turn creates steam of aerosols that may contain blood and fluid products (Ulmer, 2008).

Particle size

Living cells have a size of about 15 microns (Bjålie et al., 1998). The smoke generated by the use of heat-producing medical devices includes ultrafine particles (UFP) of less than 0.1 microns (Näslund Andreasson, 2011).

Particle size in surgical smoke using diverse medical technical equipment (Alp et al., 2006; Ulmer, 2008)

Equipment	**Mean aerodynamic particle size**
Diathermy	0,07 µm
Laser	0,31 µm
Ultrasonic dissection	0,35 - 6,5 µm

Particle size for various substances according to De Boorder et al. (2007)

Substance	**Size in micron**
Viruses	0,01 - 0,3 µm
HIV	0,18 µm
HPV	0,045 µm
Bacteria	0,3 - 15,0 µm
Mycobacterium tuberculosis	0,5 – 5,0 µm
Lung-damaging smoke	0,5 - 5,0 µm
Tobacco smoke	0,1 - 3,0 µm
Surgical smoke	0,1 - 5,0 µm
Smallest visible particle	20 µm

The smaller a particle is the more deeply it may penetrate in the respiratory-organ and if a particle is less than 2.5 micron, it can be transported to the bronchi and alveoli, where gas exchange occurs. If the particle is 5 microns or larger it usually stuck in the bronchi, trachea, pharynx or upper respiratory tract (Brüske-Hohfeld et al., 2008; Ulmer, 2008).

Components

Ultrafine particles (UFP) formed during combustion of materials such as tobacco, wood, candles, asphalt plant, car exhaust, etc. (Näslund Andreasson, 2011). The literature review by Lindsay et al. (2015) points out that diathermy smoke contains chemical and biological

substances that are considered as mutagenic, carcinogenic, and possibly infectious. They mean further on that the smoke contains whole cells and viral particles.
UFP found in smoke when using electrosurgical equipment should be seen as toxic as they contain cell debris and gaseous chemicals substances, particles can be deposited in the alveoli, Nyman wrote in 1996 in SEORNA's Journal "Uppdukat". Mowbray et al. (2013) highlights that there are infected and malignant cells in the smoke. Tomita et al. described even earlier, in 1981 in Mutation Research that smoke from the carbon dioxide laser from 1 gram of burned tissue had comparable mutagenic values from smoke of 6 cigarettes. The smoke contains dead and living cell material from the patient's tissue, HPV DNA, toxic gases, mutagenic and carcinogenic materials (AORN, 2014; Nyman, 1996; Tomita et al., 1981; Ulmer, 2008; Watson, 2010).
There are many chemical substances occurring in surgical smoke, and the most common are hydrocarbons, fatty acids, phenols and nitriles according to Barrett and Garber (2003). The substances described in the literature as hazardous and need attention are for example; acrylonitrile, hydrogen cyanide, benzene and toluene, which are described by Naslund Andreasson (2011). Choi et al. (2014) have identified 18 of 52 different volatile organic compounds in the surgical smoke, of which 5 were carcinogenic in relation to surgery of radical or partial nephrectomy for renal cell carcinoma.

Effects of surgical smoke

According to Alp et al. (2006), these chemicals named above may be absorbed through the skin and lungs. They have a toxic effect that can affect irritation of the eyes, nausea and vomiting, headache, sneezing, weakness and dizziness. Even emphysema, asthma and chronic bronchitis can be caused by surgical smoke. Benzene is documented as a "trigger" for leukemia (Ulmer, 2008).
Carbon monoxide is particularly problematic for the patient during laparoscopic surgery, because the risk of absorbing carbon monoxide through the peritoneum into the blood stream. Carbon monoxide, form together with hemoglobin carboxyhemoglobin as HbCO, and methemoglobin as MetHb (Ball 2001; Dåvöj et al. 2012; Ott 1998). Increased amounts of HbCO and MetHb cause hypoxic stress in healthy individuals through reduced oxygen-carrying capacity. In patients with cardiovascular disease this could result in a deterioration of cardiovascular function, other symptoms are also described in the report from Watson (2010). Patients who underwent surgery for laparoscopic cholecystectomy, Dobrogowski et al. (2014), found significantly increased levels of benzene and toulene in the patients' urine postoperatively compared with preoperatively. The conclusion was that the smoke in the intraabdominal room was absorbed by the peritoneum and transported through the bloodstream to the urinary tract.

Distance of smoke, spread of smoke

In the environment, due to the spread of smoke, it can be seen that the smoke from various medical devices spreads in different ways. De Boorder et al. (2007) who studied the smoke from electrosurgery and carbon dioxide laser could see the smoke of carbon dioxide laser was spread more explosive and further away from the surgical field compared to the smoke from electrosurgery. When evacuation system is used the smoke are gathering more effectively regardless of medical device, but they do not capture aerosols. The aerosols are heavy and fall downwards, the risk is less to inhale large aerosols. Bruske-Hohfeld et al. (2008) showed that high concentrations of ultrafine particles (UFP) occurs over short exposure periods during abdominal surgery, the highest concentration was during hemihepatectomy and at the smallest amount was during laparoscopic appendectomy.

Kim et al. (2014) studied the effects of laminar and turbulent flow of surgical smoke at ultrasound dissections during laparoscopic procedures. The result show when a curved-blade was used, the smoke had turbulent flow which minimized the field of view for the surgeon. Straight-blades generated laminar flow, which made the vision became clearer and the smoke disappeared fast from the surgical view. Teflon-coated blades and feedback mode when using electrosurgery was associated with reduced amount of surgical smoke according to Kisch et al. (2015).

Prevention and protection against surgical smoke

First and foremost there must be a ventilation in the operating room with the correct number of air changes. Conventional ventilation, has at least 15 air exchanges/hour, and the air is filtered or it may be ventilation where laminar airflow are used. In normal ventilation ultrafine particles (UFP) disappears in the operating room until 20 minutes after the use of electrosurgery according to Brandon et al. (1997 in Benson et al., 2013).

Evacuation systems

A Central evacuation system is powerful and they are quieter than mobile evacuation systems as it is installed outside the operating room (Ulmer, 2008). Mobile evacuation system - The best effective system is the triple filter system with an ULPA (ultra-low particulate air) -filter or HEPA (high efficiency particulate air) -filter, which take particles 0.1 microns and larger, the capacity is nearly 100% (one particle in a million escapes). The systems have a pre-filter which catches the largest particles. The ULPA filter is the second stage of the filtration. The final filter is an activated charcoal filter that absorbs toxic chemical ingredients and the odors in the smoke. It is important to place the diathermy-pen with its suction within 2 cm from the source of smoke production. Notable is, if the inside diameter of the suction hose is too tight, it may give unacceptable noise levels. Factors affecting the capability of capturing the smoke; the capacity of aspiration flow (liters/min), the distance between the suction and the source of smoke production, the inner diameter of the suction hose and the amount of smoke produced during the operation (Schultz, 2014). Laparoscopic evacuation system: special filters are available.

Personal protective equipment

To reduce exposure for surgical smoke, personal protective equipment is used.
It is important to protect the respiratory system, the eyes and the skin (Benson et al. 2013). The eyes need protection by glasses and for the skin a coat and gloves are appropriate safeguards. An effective evacuation system is probably the most important arrangement today and that the operating room personnel follows the instructions for the medical devices that generates smoke. Developments is done quite rapidly and in the future there may be other methods of preventions and protections. Face masks used today, filter particles 5 microns or larger, according to Ulmer (2008) and Benson et al. (2013). Respirators as FFP3 can filter particles that are 0.1 microns (Ulmer, 2008; Benson et al., 2013).
Respirators are classified according to European Standard EN 149: 2001 + A1: 2009.
De Boorder et al. (2007) argues that the most effective is respirators with HEPA filters. When using respirators it must be put on correct according to the manufacturer's instructions, otherwise it has no effect and one shouldn't visit the hazardous area (3M). Of importance is also the length of time used because the effect diminishes over time. Benson et al. (2013) claims that if the operating room personnel can feel the smell of the surgical smoke it is probably hazardous and infected materials, particles and pollutants spreading into the atmosphere and this may cause illnesses. They further argue that the face mask or the alternative respirator is

"the last line of defense" against inhalation of ultrafine particles (UFP), and as health care personnel it is important to be able to assess what is relevant to use!

Issues to be included in the assessment; Is there an effective evacuation system? Is the exposure time calculated? What is the effect setting? What is the surgery to be performed? What is the patient's age and BMI? Is there a risk of infection? Choi et al. (2014) points out that the operating room personnel and especially the surgeon should not be exposed to surgical smoke, and the personnel should use the protection equipment provided, because it will not be known until after several decades, what risks they have been exposed to.

Filter replacement

The waste, thus changing filters in the evacuation systems should be considered as infectious materials according to AORN (2014) because it is waste from surgical smoke. It may remain a risk to inhale ultrafine particles (UFP) and filters should be sealed effectively to prevent particles from entering the room air. Important to remember in this situation, when changing the filters, is to protect the lungs and respiratory system, to wear eye protection and gloves, as well as protection of the working suit against contamination.

Education and training

Education and information about protections and preventions should be held and be available, specifically requires training to take on respirators properly according to Benson et al. (2013). In Europe, the employer have to inform the workers about proper donning of protective respirators FFP 3 (European Commission, 2010). Ball (2010) found out; the more knowledge and training operating room nurses had in the field of surgical smoke, the better was compliance to smoke evacuation systems during operations.

EU Directive

Legislation in Europe aims to minimize the health risks of biological agents at the workplace (European Parliament and Council Directive 2000/54 / EC on the protection of workers from risks related to exposure to biological agents at work). These regulations are minimum requirements which must be transposed into national law. In the directive biological agents are divided into 4 risk groups depending on whether they can cause diseases and the possibilities of prevention and treatment. In the index list of the Directive, it is listed potential allergenic or toxic effects of biological agents. When it comes to activities that could pose a risk of exposure to biological agents, the nature, degree and duration of workers' exposure must be determined in order to make it possible to assess the risks for the workers' health or safety and to determine the measures to be taken. In the Directive includes measures described for mitigation (European Agency, 2003).

The Directive requires the employer to:

- Assess the risks posed by biological agents
- Reduce the risk to the workers by:
    - elimination or substitution
    - exposure prevention and control
    - information and training of the workers, and
- Provide health surveillance as appropriate

There is more to find out about in the field of surgical smoke, this is only a small part that has been illuminated and it is in no way complete. Developments and research for prevention and

protection of surgical smoke continues hopefully for patients and the surgical team-members, for them to receive a better environment.
There is more to read at https://osha.europa.eu

I hope you will have an interesting reading!

References

3M^{TM} Technical Datasheet. https://multimedia.3m.com/mws/media/1313154O/aura.pdf [Assessed: 2017-01-02]

Alp, E., Bijl, D., Bleichrodt, R.P., Hansson, B., & Voss, A. (2006). Surgical smoke and infection control. *Journal of Hospital Infection* 62(1), 1-5.

AORN (2014). Recommended practices for electrosurgery. *Perioperative Standards and Recommended Practices. For Inpatient and Ambulatory Settings.* Denver: Association of perioperative Registered Nurses.

Ball, K. (2010). Surgical smoke evacuation guidelines: compliance among perioperative nurses. *AORN Journal* 92(2), e1-e23.

Ball, K. (2001). The hazards of surgical smoke. *AANA Journal* 69 (2), 125-132.

Barrett, W.L. & Garber, S.M. (2003). Surgical smoke – a review of literature. Is this just a lot of hot air?? *Surgical Endoscopy* 17, 979-987.

Benson, S.M., Novak, D.A., & Ogg, M.J. (2013). Proper use of surgical N95 respirators and surgical masks in the OR. *AORN Journal*, 97(4), 458-467.

Bjålie, J.G., Haug, E., Sand, O., Sjaastad, Ø.V., & Toverud, K.C. (1998). *Människokroppen. Fysiologi och anatomi.* 7th Ed. Stockholm: Liber. *(In Swedish)*

Brüske-Hohfeld, I., Preissler, G., Jauch, K-W., Pitz, M., Nowak, D., Peters, A., & Wichmann, H-E. (2008). Surgical smoke and ultrafine particles. *Journal of Occupational Medicine and Toxicology* 3(3), 31.

Choi, S.H., Kwon, T.G., Chung, S.K., & Kim, T-H. (2014). Surgical smoke may be biohazard to surgeons performing laparoscopic surgery. *Surgical Endoscopy* 28, 2374-2380.

De Boorder, T., Verdaasdonk, R., & Klaessens, J. (2007). The visualization of surgical smoke produced by energy delivery devices: significance and effectiveness of evacuation systems. Proc. Of SPIE 6440, 64400R-1-64400R-7

Dobrogowski, M., Wesolowski, W., Kuchsarska, M., Sapota, A., & Pomorski, L.S. (2014). Chemical composition of surgical smoke formed in the abdominal cavity during laparoscopic cholecystectomy – assessment of the risk to the patient. *International Journal of Occupational Medicine and Environmental Health* 27(2), 314-325.

Dåvöj, G.M., Hansen, I., & Eide, P.H. (2012). *Operationssjukvård. Operationssjuksköterskans perioperativa omvårdnad.* Lund: Studentlitteratur. *(In Swedish)*

European Agency for Safety and Health at Work. (2014). Current and emerging issues in the healthcare sector, including home and community care. European Risk Observatory Report. https://osha.europa.eu/en/tools-and-publications/publications/reports/current-and-emerging-occupational-safety-and-health-osh-issues-in-the-healthcare-sector-including-home-and-community-care/view [Assessed: 2016-12-25]

European Agency for Safety and Health at Work. (2003). Facts. 41 Biological agents. https://osha.europa.eu/tools-and-publications/publications/factsheets/41 [Assessed 2017-01-03]

European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work. Directive 2000/54/EC – biological agents at work. https://osha.europa.eu/en/legislation/directives/exposure-to-biological-agents/77 [Assessed 2017-01-01]

European Commission. (2010). *Occupational health and safety risks in the healthcare sector. Guide to prevention and good practice.* Luxemburg: The Publications Office of the European Union, 2013. http://studylib.net/doc/18917608/occupational-health-and-safety-risks-in-the-healthcare [Assessed 2017-01-01]

Hallmo, P., & Naess, O. (1991). Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. *European Archives of Otorhinolaryngology* 248, 425-427.

In, S.M., Park, D-Y., Sohn, I.K., Kim, C-H., Lim, H.L., Hong, S-A., Jung, D.Y., Jeong, S-Y., Han, J.H., & Kim, H.J. (2015). Experimental study of the potential hazards of surgical smoke from powered instruments. *British Journal of Surgery* 102, 1581-1586.

Jacobson, B., & Öberg, P-Å. (2003). *Teknik i praktisk sjukvård.* Lund: Studentlitteratur. *(In Swedish).*

Kim, F.J., Sehrt, D., Pompeo, A., & Molina, W.R. (2014). Laminar and turbulent surgical plume characteristics generated from curved- and straight-blade laparoscopic ultrasonic dissectors. *Surgical Endoscopy* 28, 1674-1677.

Kisch,T., Liodaki, E., Kraemer, R., Mailaender, P., Brandenburger, M., Hellwig, V., & Stang, FH. (2015). Electrocautery devices with feedback mode and teflon-coated blades create less surgical smoke for a quality improvement in the operating theatre. *Medicine* 94(27), 1-6.

Lindsey, C., Hutchinson, M., & Mellor, G. (2015). The nature and hazards of diathermy plumes: A review. *AORN Journal* 101(4), 428-442.

Mowbray, N., Ansell, J., Warren, N., Wall, P., & Torkington, J. (2013). Is surgical smoke harmful to theatre staff? A systematic review. *Surgical Endoscopy* 27, 3100-3107.

Nyman, S-O. (1996). Diatermirök och utsug. *Uppdukat* 2, 12-14. *(In Swedish).*

Näslund Andréasson, S. (2011). *Work environment in the operating room during cytoreductive surgery and hyperthermic intraperitoneal chemotherapy: factors influencing choice of* *protective equipment.* Avhandling. Uppsala universitet, Uppsala. http://www.avhandlingar.se/avhandling/3ca98dfac3/ [Assessed 2016-01-06]

Ott, D. (1998). Carboxyhemoglobinemia due to peritoneal smoke absorption from laser tissue combustion at laparoscopy. *Journal of Clinical Laser Medicine & Surgery* 16(6), 309-315.

Rothrock, J. (2011). Alexander's care of the patient in surgery.14th Ed. Mosby Elseveir Philadelphia.

Råghall, K. (2012). Tungbascancer – av jobbet. *Uppdukat* 24(2), 26-28. *(In Swedish).*

Schultz, L. (2014). An analysis of surgical smoke plume components, capture and evacuation. *AORN Journal* 99(2), 289-298.

Steege, A.L., Boiano, J.M., & Sweeney, M.H. (2016). Secondhand smoking in the operating room? Precautionary practices lacking for surgical smoke. *American Journal of Industrial Medicine* 59, 1020-1031.

Swedish Operating Room Nurses Association, SEORNA. (2015). Riksföreningen anser och rekommenderar om kirurgisk rök. http://www.rfop.se/media/1794/riksfoereningen-anser-och-rekommenderar-om-kirurgisk-roek.pdf [Assessed 2017-01-03]

Tomita, Y., Mihashi, S., Nagata, K., Ueda, S., Fujiki, M., Hirano, M., & Hirohata, T. (1981). Mutagenicity of smoke condensates induced by CO_2 – laser irradiation and electrocauterization. *Mutation Research* 89(2), 145-149.

Ulmer, B. (2008). The hazard of surgical smoke. *AORN Journal* 87(4), 721-734.

Wang, H-K., Mo, F., Ma, C-G., Dai, B., Shi, G-h., Zhu, Y., Zhang, H-L., & Ye, D-W. (2015). Evaluation of fine particles in surgical smoke from an urologist's operating room by time and distance. *International Urology and Nephrology* 47, 1671-1678.

Watson, D.S. (2010). Surgical smoke evacuation during laparoscopic surgery. *AORN Journal* 92(3), 347-349.

Wu, Y-C., Tang, C-S., Huang, HY., Liu, CH., Chen, Yl., Chen, DR., & Lin, YW. (2011). Chemical production in electrocautery smoke by a novel predictive model. *European Surgical research* 46(2), 102-107.