

Neurosurgery Grand Rounds

March 12, 2010

Contributing Factors of Nosocomial Infections

Chengyuan Wu

Thomas Jefferson University Hospitals

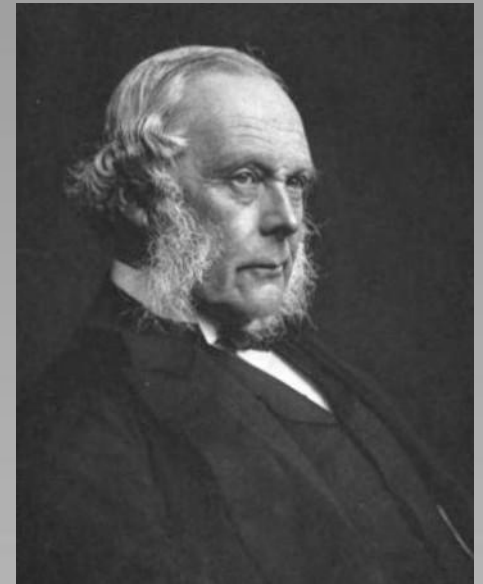
Department of Neurosurgery

Outline

- Brief History of Anti-Sepsis
- Hand-washing
- Skin preparation
- Operating Room Protocols
- Laundering of Scrubs
- Barrier Precautions

Brief History of Anti-Sepsis

- Greek physicians Galen (130–200 AD) & Hippocrates (400 BC)
- Dr. George H Tichenor experimented with the use of alcohol on wounds during the Civil War
- Dr. Ignaz Semmelweis observed decreased spread of infection by handwashing with chlorinated lime solution (*The Cause, Concept and Prophylaxis of Childbed Fever*, 1861)
- Florence Nightingale observed effects of sanitation in report on the Royal Commission on the Health of the Army (1856–1857)
- Oliver Wendell Holmes, Sr. published *The Contagiousness of Puerperal Fever* in 1843
- *Antiseptic Principle of the Practice of Surgery* (1867) by Joseph Lister
 - Used carbolic acid to sterilize surgical instruments and to clean wounds



http://en.wikipedia.org/wiki/File:Lister_Joseph.jpg

Impact of Surgical Site Infections

- SSIs are the most common form of nosocomial infection
 - 300,000 – 500,000 annually in United States
- Lead to delayed wound healing, increased hospital stays, increased use of antibiotics
 - Excess of \$1.5 billion in annual costs
- Responsible for 77% deaths in nosocomially infected surgical patients

Darouiche RO et. al. *N Engl J Med.* 2010 Jan 7;362(1):18-26.
Digison MB. *Plast Surg Nurs.* 2007 Oct-Dec;27(4):185-9.



HANDWASHING

The single most critical measure for
reducing the risk of transmitting microorganisms

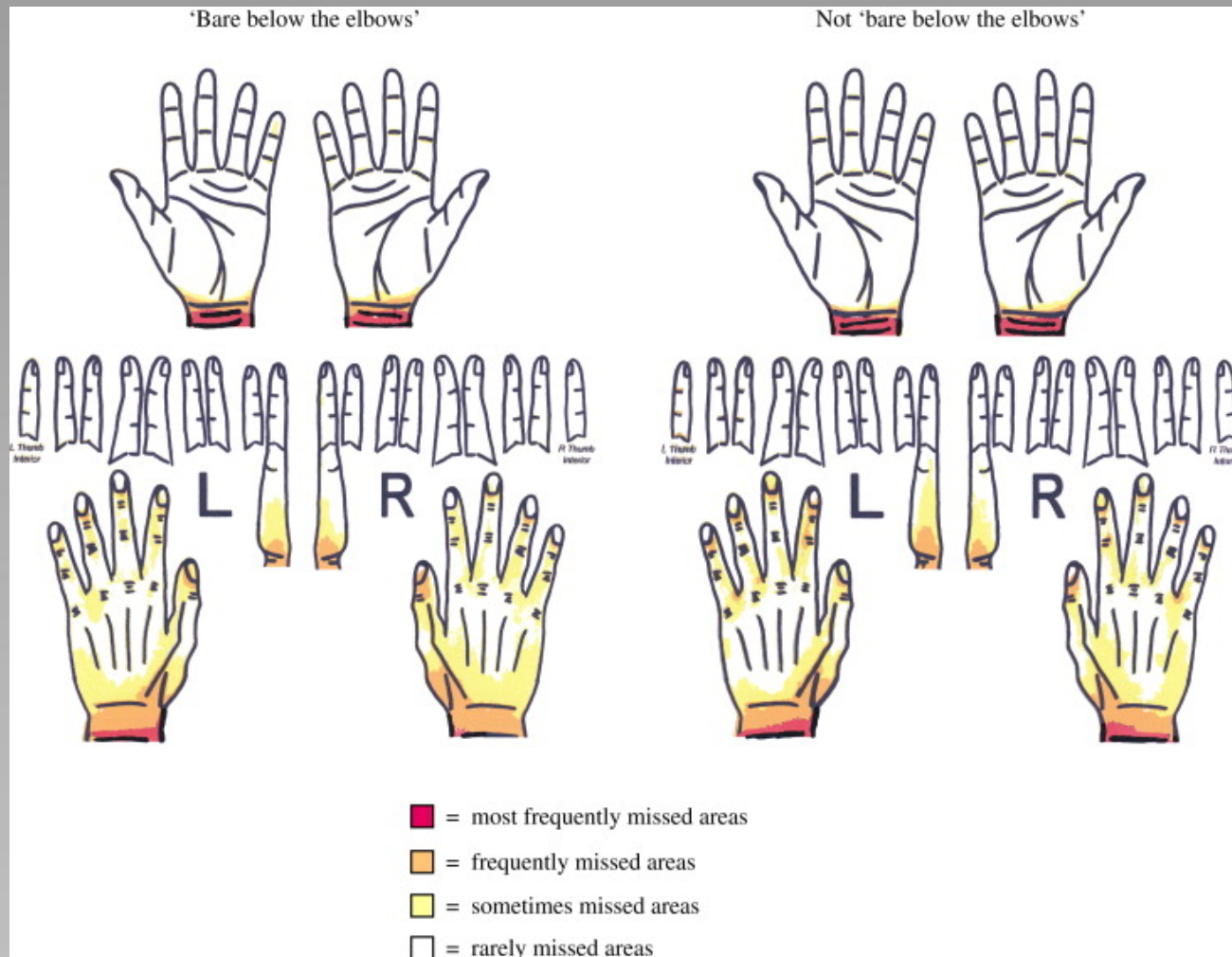
<http://implantblog.files.wordpress.com/2007/12/handwashing.jpg>

“Bare below the Elbows”

- UK Department of Health
- No sleeves, watches, or hand jewelry
 - Facilitate effective hand washing
- RCT involving 149 physicians/medical students
 - No significant difference in percentage area of hands missed
 - Only significant difference in wrist coverage
 - 38.9% missed for BBE vs 52.8% missed

Farrington RM et. al. *J Hosp Infect.* Jan 2010;74(1):86-8.

“Bare below the Elbows”



Farrington RM et. al. *J Hosp Infect.* Jan 2010;74(1):86-8.

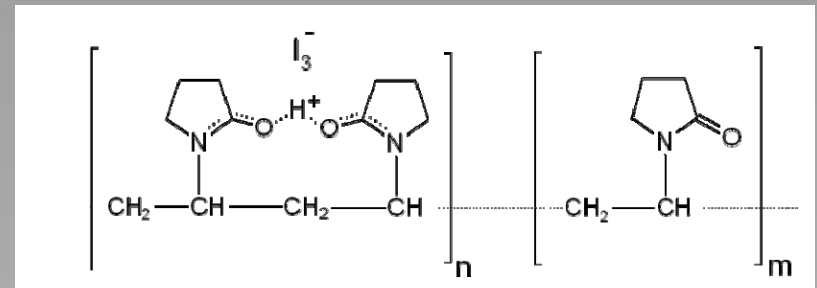
Traditional Scrub vs 'Dry' Scrub

- 2002 RCT held at multiple centers in France
 - 5 minute traditional scrub vs 5mL aqueous alcohol
 - No significant difference in SSI rates
 - 2.48% for traditional scrub
 - 2.44% for aqueous alcohol
- Improved compliance with aqueous alcohol
 - Protocol based on amount used
 - Less skin dryness/irritation

Parienti JJ et. al. *JAMA*. August 2002; 288(6): 277-727.

Povidone-Iodine

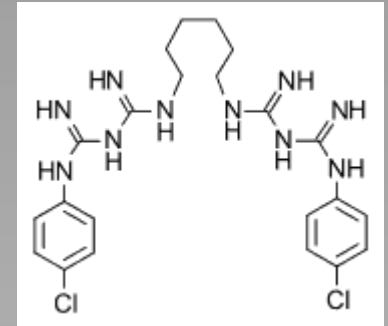
- Mechanism of iodination of lipids and oxidation of cytoplasmic and membrane compounds
 - Bactericidal
- Activity against bacteria, fungi, protozoa, and viruses
- *Betadine*



http://www.readymaderesources.com/cart/images/uploads/betadine_family.jpg

Chlorhexidine

- Mechanism of membrane disruption
 - Bactericidal and/or bacteriostatic
- More effective against gram-positive than gram-negative bacteria
 - Also some antifungal and antiviral activity
- Immediate, persistent, and residual antimicrobial properties
- *Peridex, Chloraprep, Hibiclens*



<http://www.hpnonline.com/inside/2009-06/0906/IC-chloraprep.jpg>

Alcohol vs. Chlorhexidine vs Iodine

- Better reduction of CFU with aqueous alcohol*

Logarithmic reduction in Colony Forming Units			
	1 minute	3 hours	6 hours
Alcohol	2.90	1.58	1.94
Chlorhexidine Gluconate	1.68	1.08	0.86
Povidone Iodine	1.20	0.71	-0.21

- In formulations with both, concentration of alcohol was significant but not type of alcohol§

*Parietti JJ et. al. *JAMA*. August 2002; 288(6): 277-727.

§Tanner J et. al. *Cochrane Database Syst Rev*. 2008 Jan 23;(1):CD004288.

Scrub Duration

- CDC recommends 2-6 minutes
- No difference in CFUs from 2 min to 3 min scrub
- Decrease in CFUs after 2 hours with 3 minute rub compared to 30 second rub
 - 3 minute rub as effective as 5 minute rub
- But no studies directly using SSI as endpoint

Tanner J et. al. *Cochrane Database Syst Rev.* 2008 Jan 23;(1):CD004288.

Skin Preparation

- 66% of SSIs are confined to the incision
- Gram positives isolated 2.5 times more than gram negatives

Darouiche RO et. al. *N Engl J Med.* 2010 Jan 7;362(1):18-26.

Sterile vs Clean Prep Kits

- Preoperative prep disinfects not sterilize
 - 20% resident skin flora not removed
- 1997 study of 60 patients
- Half of prep kits randomly sterilized
- No difference in residual microbial skin flora
 - Samples taken before prep, 10 minutes after prep, and after skin closure

Pearce BA et. al. *AORN J.* 1997 Sep;66(3):464-70.

Scrub & Paint vs Paint only

- 2005 RCT of 234 patients in California
 - 5 minute Betadine scrub → Betadine paint
 - Betadine paint only
- No difference in SSI rates
 - 10% in scrub + paint
 - 10% in paint only
- Skin CFUs actually higher with scrub + paint

Ellenhorn JD et. al. *J Am Coll Surg.* 2005 Nov;201(5):737-41.

Selection of Antiseptic

- Chlorhexidine more effective in preventing catheter-related bloodstream infections
 - Also has more persistent effect
- Combination of CHG and alcohol most effective

TABLE 1 Efficacy of Anti-septic Agents

Anti-septic product	FDA category	Broad spectrum	Immediate action	Persistence
Parachlorometaxlenol (Techni-Care-Care-Tech Laboratories, Inc)	I (safety) III (efficacy)	Fair	Intermediate	Good
Povidine-iodine (ScrubCare-Cardinal Health)	I	Good	Intermediate	Minimal
Chlorhexidene gluconate (Hibidens-Molnlycke Health Care)	New drug	Fair to good	Intermediate	Very good
Isopropyl alcohol/iodophor (Duraprep™-3M Healthcare Professionals)	New drug	Good	Rapid	Very good
Chlorhexidene gluconate with alcohol (Chloraprep®-Medi-Flex)	New drug	Very good	Rapid	Very good
Alcohol with zinc pyrithione (Actiprep-HealthPoint)	I	Very good	Rapid	Very good

Digison MB. *Plast Surg Nurs.* 2007 Oct-Dec;27(4):185-9.

ORIGINAL ARTICLE

Chlorhexidine–Alcohol versus Povidone–Iodine for Surgical-Site Antisepsis

Rabih O. Darouiche, M.D., Matthew J. Wall, Jr., M.D., Kamal M.F. Itani, M.D., Mary F. Otterson, M.D., Alexandra L. Webb, M.D., Matthew M. Carrick, M.D., Harold J. Miller, M.D., Samir S. Awad, M.D., Cynthia T. Crosby, B.S., Michael C. Mosier, Ph.D., Atef AlSharif, M.D., and David H. Berger, M.D.

ABSTRACT

BACKGROUND

Since the patient's skin is a major source of pathogens that cause surgical-site infection, optimization of preoperative skin antisepsis may decrease postoperative infections. We hypothesized that preoperative skin cleansing with chlorhexidine–alcohol is more protective against infection than is povidone–iodine.

METHODS

We randomly assigned adults undergoing clean-contaminated surgery in six hospitals to preoperative skin preparation with either chlorhexidine–alcohol scrub or povidone–iodine scrub and paint. The primary outcome was any surgical-site infection within 30 days after surgery. Secondary outcomes included individual types of surgical-site infections.

RESULTS

A total of 849 subjects (409 in the chlorhexidine–alcohol group and 440 in the povidone–iodine group) qualified for the intention-to-treat analysis. The overall rate of surgical-site infection was significantly lower in the chlorhexidine–alcohol group than in the povidone–iodine group (9.5% vs. 16.1%; $P=0.004$; relative risk, 0.59; 95% confidence interval, 0.41 to 0.85). Chlorhexidine–alcohol was significantly more protective than povidone–iodine against both superficial incisional infections (4.2% vs. 8.6%, $P=0.008$) and deep incisional infections (1% vs. 3%, $P=0.05$) but not against organ-space infections (4.4% vs. 4.5%). Similar results were observed in the per-protocol analysis of the 813 patients who remained in the study during the 30-day follow-up period. Adverse events were similar in the two study groups.

CONCLUSIONS

Preoperative cleansing of the patient's skin with chlorhexidine–alcohol is superior to cleansing with povidone–iodine for preventing surgical-site infection after clean-contaminated surgery. (ClinicalTrials.gov number, NCT00290290.)

Darouiche RO et al. *N Engl J Med.* 2010 Jan 7;362(1):18-26.

Chloraprep vs Betadine

- April 2004 to May 2008
- 2% chlorhexidine gluconate & 70% isopropyl alcohol vs Povidone-Iodine
- Endpoint of SSI within 30 days
- Relative risk of SSI 0.59 with Chloraprep
 - Similar to 49% reduction in risk of central line placement

Darouiche RO et. al. *N Engl J Med.* 2010 Jan 7;362(1):18-26.

Neurotoxicity of Chloraprep



United States -ENG

Chloraprep®

Patient Preoperative Skin Preparation
2% Chlorhexidine Gluconate (CHG) & 70% Isopropyl Alcohol (IPA)

Search

[Chloraprep](#) > [Using Chloraprep](#) > [Labeled Warnings](#)

What is Chloraprep?

Why Skin Prep Matters

Product Line

Using Chloraprep

[Formulation](#)

[Skin Prep Checklist](#)

[Labeled Warnings](#)

[Product Education and Usage](#)

Customer Support

Contact Us

Labeled Warnings

Chloraprep should not be used:

- In children less than 2 months of age because of the potential for excessive skin irritation and increased drug absorption
- On patients with known allergies to chlorhexidine gluconate or isopropyl alcohol
- **For lumbar puncture or in contact with the meninges**
- On open skin wounds or as a general skin cleanser
- In or around eyes, ears and mouth. May cause serious or permanent injury if permitted to enter and remain

Additional labeled warnings of Chloraprep include:

- Solution contains alcohol and gives off flammable vapors — allow to dry three minutes on skin
- Do not drape or use ignition source (e.g., cautery, laser) until product is completely dry (minimum of 3 minutes on hairless skin)
- Avoid getting solution into hairy areas. Solution may take much longer to dry or may not dry completely
- Do not allow the solution to pool
- Remove any soaked materials, drapes, and gowns before using ignition sources
- Whenever prepping the neck area, place towels under each side to absorb excess solution

Customer Support

[Call](#) with questions.
[Contact us by e-mail.](#)

Monday – Friday
7 a.m. to 5 p.m. CST

[How to Order](#)

Related Information

[Formulation](#)

[Clinical Studies](#)

[Evidence-based Guidelines](#)

www.chloraprep.com

Neurotoxicity of Chloraprep

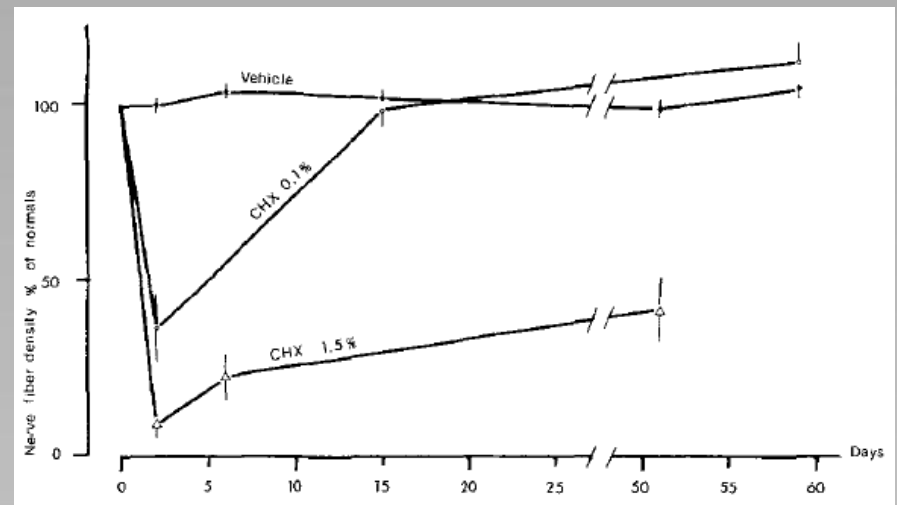
- Mechanism of membrane disruption
 - Minimal percutaneous penetration
- 1955 study showed toxicity of many compounds injected into CSF of monkeys
- 1971: reports of sensorineuronal hearing loss after otosurgery using chlorhexidine prep
 - Inner ear damage related to concentration and duration of exposure

Henschen A, Olson L. *Acta Neuropathol.* 1984;63(1):18-23

Neurotoxicity of Chloraprep

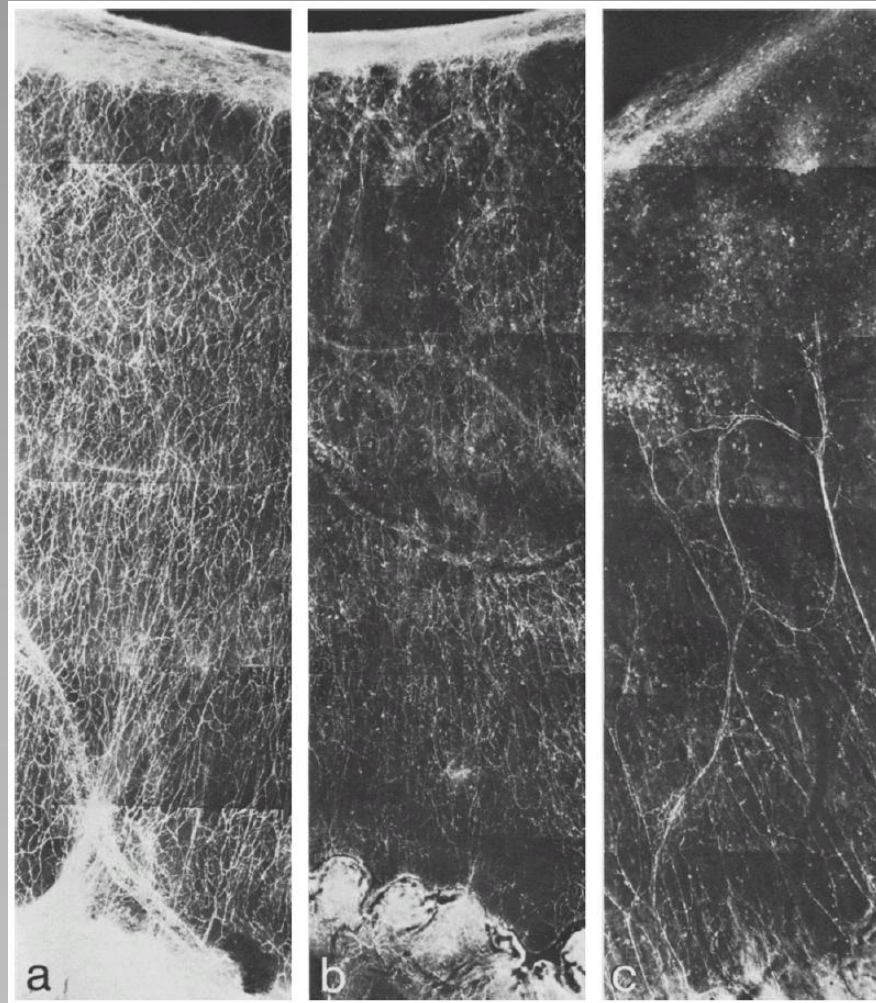
- Rat experiment performed in Sweden (1984)
 - Chlorhexidine injected into anterior chamber of eye
 - Examined iris at 2, 6, 15, 51, and 59 days
- Dose-dependent degeneration of nerves
- Primarily effects axon terminals and spares preterminal axon bundles

Concentration	Remaining nerves at 2 days
0.05%	70%
0.1%	25%
1.5%	5%



Henschen A, Olson L. *Acta Neuropathol.* 1984;63(1):18-23

Neurotoxicity of Chloraprep



Henschen A, Olson L. *Acta Neuropathol.* 1984;63(1):18-23

Neurotoxicity of Chloraprep

- 2008 Study performed at Johns Hopkins
 - Retrospective analysis of patients with lumbar drains
- Changed prep from iodine to chlorhexidine solution
 - Infection rate lowered to 1.8% from 4.7% (not significant)
 - At least equally as effective
- No mention of adverse effects with use of chlorhexidine of 60 month period

Greenberg BM, Williams MA. *Neurosurgery*. 2008 Feb;62(2):431-5.

Neurotoxicity of Chloraprep

- 1990 RCT performed at Stanford on 57 patients
 - Chlorhexidine impregnated sponge dressing used for indwelling epidural catheters
- 29% vs 3.8% catheters colonized at time of removal
 - Catheters left in place 2-8 days
 - Most common isolate of *Staphylococcus epidermidis*
- “There were no reported or observed adverse effects from the dressing”

Shapiro JM et. al. *Anesthesiology*. 1990 Oct;73(4):625-31.

Toxicity of Betadine

- 2009 study performed in China
- Injection of Betadine into conjunctival sac and anterior chamber of rabbits
 - Severe epithelial damage at concentrations $\geq 2.5\%$
 - Significant corneal edema seen at concentrations $\geq 1.5\%$
- No direct evaluation of neurotoxicity

Jiang J et. al. *Cutan Ocul Toxicol.* 2009;28(3):119-24.

Preoperative Hair Shaving

- 1891 Dr. Rosewell Park , Univ of Buffalo
 - Advised shaving 4 days prior and immediately prior
 - Also recommended surgeon to have short hair and shave

Pros

Clarify orientation
Facilitate skin marking
Expedite closure
Ease of dressing placement
Perceived decrease in infection

Cons

Change/Loss of protective skin flora
Microtrauma can increase bacterial colonization
Cosmesis
Improved patient morale

Siddique MS et. al. *Br J Neurosurg.* 1998 Apr;12(2):131-5.

Preoperative Hair Shaving

- 1980 study in Canada of 62,339 surgical wounds
 - 2.5% infection with manual razor
 - 1.4% infection with electric razor
 - 0.9% infection with no shave

Cruse PJ, Foord R. *Surg Clin North Am.* 1980 Feb;60(1):27-40

Preoperative Hair Shaving

- First large series in 1992, Univ. of Colorado
 - 638 patients with infection rate of 1.1%
- 2001 cohort study performed in Turkey^{*}
 - 1038 patients
 - 1.22% for shave vs 1.25% for no shave
- 2001 study in the UK also showed no difference[§]
 - CFUs did not correlate with infection rates

^{*}Bekar A et. al. *Acta Neurochir (Wien)*. 2001;143(6):533-6
[§]Tang K *Pediatr Neurosurg*. 2001 Jul;35(1):13-7.

Preoperative Hair Shaving

- 2009 series of 632 patients in Japan
 - All underwent craniotomy/burr hole without shaving
 - Care taken to keep hair out of wound on closure
 - Hair shampooed regularly postoperatively
- 1.1% developed wound infections

Tokimura H. et. al. *J Craniomaxillofac Surg.* 2009 Dec;37(8):477-80.

Preoperative Hair Shaving

- 2001 retrospective study, Medical U of S Carolina
 - 250 patients over 2½ year period
 - No difference in preoperative routine

	Infection rate	Mild	Moderate	Severe
Shave	6 (6%)	4 (4%)	2 (2%)	0 (0%)
No Shave	11 (7%)	6 (4%)	5 (3%)	0 (0%)

Miller JJ et. al. *Otol Neurotol*. 2001 Nov;22(6):908-11

Preoperative Hair Shaving

- 2007 RCT of 789 spine patients in Istanbul
 - No other changes in preoperative preparation
- 1.07% infection rate in shaved group
- 0.23% infection rate in unshaved group
- Duration of procedure was no different
 - Not felt to impede performance of procedure

Celik SE, Kara A..*Spine*. 2007 Jul 1;32(15):1575-7.

Operating Room Behavior

- 2009 study performed in Switzerland
- Standard protocol vs. Extensive antiseptic measures
 - Use of iodine-impregnated covering
 - All surgeons wear caps that cover ears and neck
 - All surgeons wear 2 pairs of gloves
 - Gloves changed every 2 hours
 - Field re-draped prior to closure
 - Gloves changed after closure of fascia
 - At least 5L irrigation

Beldi G et. Al. *Am J Surg.* 2009 Aug;198(2):157-62

Operating Room Behavior

- Primary end point of SSIs
- 'Discipline Score'
 - Violations in sterile technique
 - Skin preparation/Surgical draping
 - Hand washing
 - Proper attire
 - Distance of 50cm maintained by nonsterile persons
 - Exchange of surgical team members
 - Movement in the OR
 - OR noise
 - Visitors
 - Intraoperative changing of patient position

Beldi G et. Al. *Am J Surg.* 2009 Aug;198(2):157-62

Operating Room Behavior

- 15% cases with SSI for Extensive Antisepsis
- 14% cases with SSI for Standard Protocol

Multivariate analysis of risk factors

	Odds ratio (95% CI)	<i>P</i> value
BMI (≤ 30 kg/m ² \rightarrow > 30 kg/m ²)	2.00 (1.22–3.20)	.006
Surgeon (consultant \rightarrow fellow)	1.27 (.80–2.03)	.32
Duration of surgery (≤ 3 h \rightarrow > 3 h)	3.34 (1.82–6.14)	$< .001$
Discipline score (0 \rightarrow ≥ 1)	2.02 (1.05–3.88)	.04
Intestinal anastomosis	6.74 (3.42–13.30)	$< .001$

BMI = body mass index; CI = confidence interval.

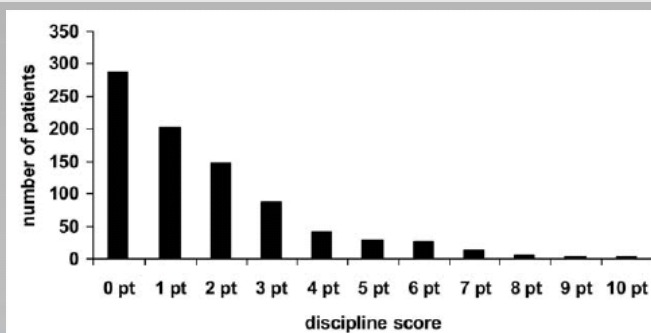
Beldi G et. Al. *Am J Surg.* 2009 Aug;198(2):157-62

Operating Room Behavior

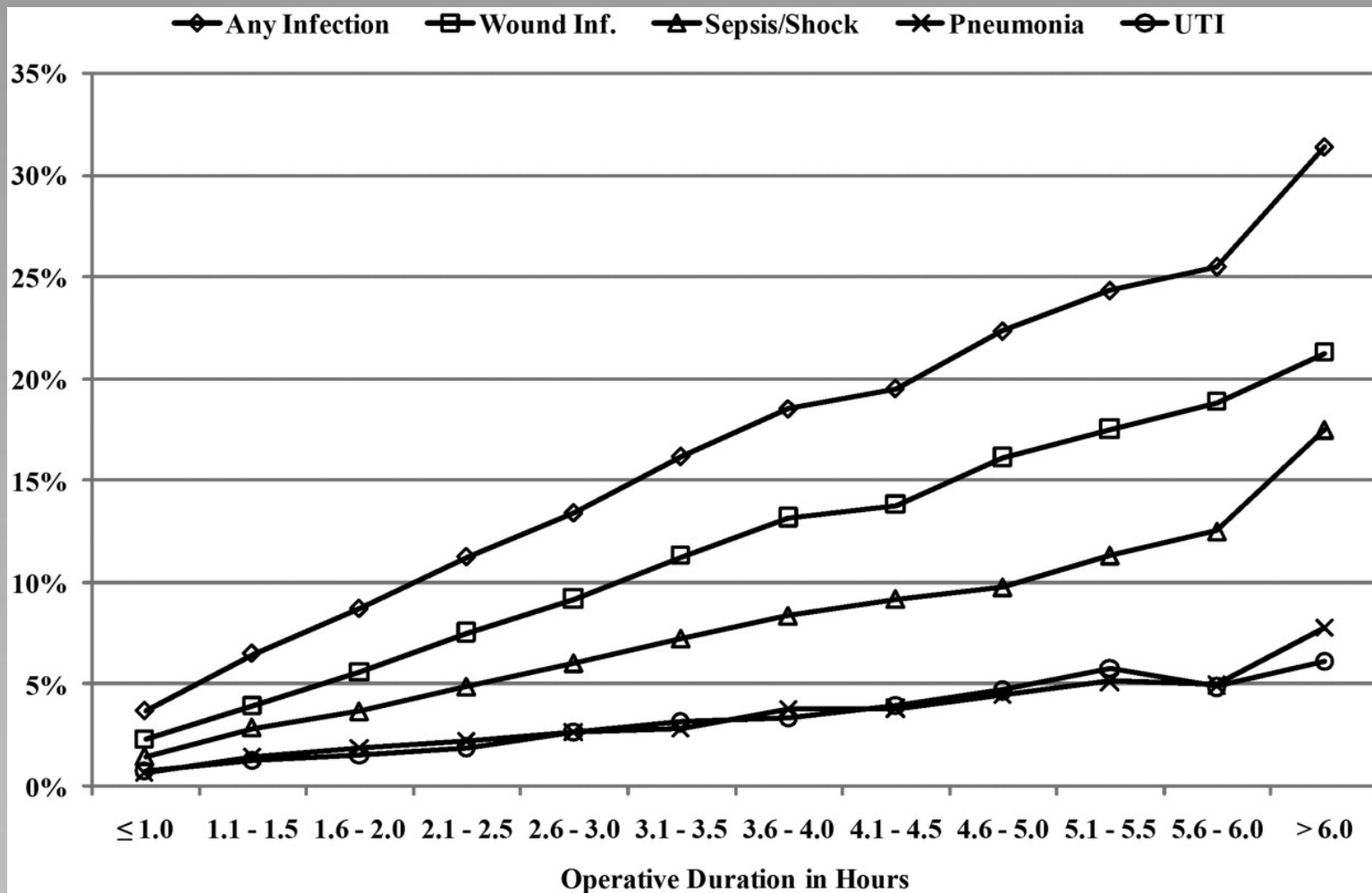
Univariate analysis of the factors assessed to evaluate the adherence to principles of asepsis (discipline) of surgical team members

	Correct/factor absent no. (%)	Not correct/factor present no. (%)	Relative risk	95% CI	P
General impression	115/767 (15.0)	2/26 (7.7)	.513	.134–1.964	.407
Preparation of patient	108/752 (14.4)	9/41 (22.0)	1.528	.836–2.794	.178
Hand scrub	111/768 (14.5)	6/25 (24.0)	1.661	.809–3.407	.244
Type of cap/mask	100/702 (14.2)	17/91 (18.7)	1.311	.823–2.089	.272
Distance to surgical tables maintained	104/722 (14.4)	13/71 (18.3)	1.271	.754–2.144	.381
Exchange of surgical team members	37/450 (8.2)	80/343 (23.3)	2.837	1.972–4.080	<.001
Movement in operative room	104/742 (14.0)	13/51 (25.5)	1.819	1.101–3.005	.039
Noise	57/507 (11.2)	60/286 (21.0)	1.866	1.338–2.602	<.001
Visitors	79/625 (12.6)	38/168 (22.6)	1.789	1.264–2.533	.002
Change of patient's position	110/761 (14.5)	7/32 (21.9)	1.513	.769–2.979	.304

CI = confidence interval.



Surgical Duration



Procter LD et. al. *J Am Coll Surg*. 2010 Jan;210(1):60-5.e1-2.

Perioperative Inspired FiO_2

- Tissue oxygen tension
 - Oxidative killing by neutrophils
 - Collagen formation, neovascularization, epithelialization
 - Antibiotics requiring oxygen
- 2000 RCT on 500 patients performed in Austria
 - 80% oxygen vs. 30% oxygen
 - 5.2% vs. 11.2% SSIs

Greif R et. al. *N Engl J Med.* 2000 Jan 20;342(3):161-7.

Perioperative Inspired FiO_2

- Subsequent studies with varied results
 - Other factors contributing to tissue oxygen tension
 - Fluid status
 - Temperature
- Meta analysis of 3001 patients
 - 9% SSIs in 80% FiO_2 group
 - 12% SSIs in 30% FiO_2 group

Hunt TK, Hopf HW. *JAMA*. 2009 Oct 14;302(14):1588-9.

Perioperative Inspired FiO_2

- PROXI trial performed at 14 Danish hospitals
- 1386 patients undergoing surgery 2006 - 2008
 - Less fluid administered intraoperatively
 - Normothermia could not be maintained in all cases
- No difference between two groups
 - 19.1% in 80% FiO_2 group
 - 20.1% SSIs in 30% FiO_2 group
- No difference of pulmonary complications

Meyhoff CS et. al. *JAMA*. 2009 Oct 14;302(14):1543-50.

Laundering of Scrubs

- CDC statement: “There are no well-controlled studies evaluating scrub suit laundering as an SSI risk factor.”
- Multiple studies showing increased levels of contamination of scrubs without ‘cover gown’
 - 2000 study showed that “no evidence supports using cover gowns for infection control reasons.”

Belkin NL. *Am J Infect Control*. 2001 Feb;29(1):58-64.

Laundering of Scrubs

- National Institute for Occupational Safety and Health performed study in 1995
 - Contamination of workers' homes was found to be a worldwide problem
 - Most infectious diseases transported on workers
- *Staphylococci* and *enterococci* can survive up to 90 days on certain materials

Belkin NL. *Am J Infect Control*. 2001 Feb;29(1):58-64.

Laundering of Scrubs

- Healthcare workers not wearing scrubs launder their own clothing regularly^{*}
- CDC considers transmission of blood-borne pathogens on soiled linen to be negligible
- Uniforms laundered at home have shown no link with increase in infection rates[§]
 - No pathogens recovered from home-laundered scrubs

^{*}Belkin NL. *Am J Infect Control*. 2001 Feb;29(1):58-64.
[§]Springer R. *Plast Surg Nurs*. 2008 Jan-Mar;28(1):45-6.

Laundering of Scrubs

- Pilot study of 50 HCWs in Boulder, CO
 - Cultures of scrubs laundered at home vs hospital
 - No pathogenic growth on either group
 - No significant differences of skin flora
 - 36.6% of home-laundered scrubs
 - 35% of hospital-laundered scrubs
 - Home-laundering primarily with warm water

Jurkovich P. *MCN Am J Matern Child Nurs.* 2004 Mar-Apr;29(2):106-10.

Barrier Precautions

- 2006 study performed in Canada
- RCT evaluating effect of gowns
 - Standard protocol: gowns, gloves, hand-washing
 - Intervention: gloves, hand-washing
 - alcohol-based hand disinfectant placed more prominently
- No significant change in MRSA transmission
 - Hand-washing more important than gown use

Grant J, et. al. *Infect Control Hosp Epidemiol.* 2006 Feb;27(2):191-4.

Barrier Precautions

- 2008 study performed at U Maryland
 - Factors involved in transmission of MRSA/VRE
- Risk factors
 - Patient with PEG
 - Contact with ET-tube
 - Contact with head and/or neck
- Detection more frequent on gloves than on gowns
 - 13% of those with organism detected later also had positive cultures from their hands
 - Importance of hand washing

Snyder GM et. al. *Infect Control Hosp Epidemiol.* 2008 Jul;29(7):583-9.

Summary

- Handwashing remains to be a critical part of reducing transmission of infection
- Dry rub is as effective as traditional scrub
- A 3 minute peroperative scrub is adequate
- Chlorhexidine is more effective than Betadine for preoperative hand scrubbing and skin preparation
- The neurotoxicity of chlorhexidine does not appear to be clinically significant
- Preoperative hair shaving does not decrease SSIs
- Operative duration is directly proportional to rates of infection
- Repetitive minor breaches in sterile technique contribute more to infection than a frank contamination
- Home laundering of scrubs does not increase SSIs
- Handwashing and glove use are more important than use of gowns

References

- "Antiseptic" Wikipedia. 10 Feb 2010. <http://en.wikipedia.org/wiki/Antiseptic>
- Beldi G, Bisch-Knaden S, Banz V, Mühlemann K, Candinas D. 'Impact of intraoperative behavior on surgical site infections.' *Am J Surg*. 2009 Aug;198(2):157-62
- Bekar A, Korfali E, Doğan S, Yilmazlar S, Başkan Z, Aksoy K. 'The effect of hair on infection after cranial surgery.' *Acta Neurochir (Wien)*. 2001;143(6):533-6; discussion 537.
- Belkin NL. 'Home laundering of soiled surgical scrubs: surgical site infections and the home environment.' *Am J Infect Control*. 2001 Feb;29(1):58-64.
- Brar MS, Brar SS, Dixon E. 'Perioperative Supplemental Oxygen in Colorectal Patients: A Meta-Analysis.' *J Surg Res*. 2009 Jul 10.
- Celik SE, Kara A. 'Does shaving the incision site increase the infection rate after spinal surgery?' *Spine*. 2007 Jul 1;32(15):1575-7.
- Cruse PJ, Foord R. 'The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds.' *Surg Clin North Am*. 1980 Feb;60(1):27-40.
- Darouiche RO, Wall MJ Jr, Itani KM, Otterson MF, Webb AL, Carrick MM, Miller HJ, Awad SS, Crosby CT, Mosier MC, Alsharif A, Berger DH. 'Chlorhexidine-Alcohol versus Povidone-Iodine for Surgical-Site Antisepsis.' *N Engl J Med*. 2010 Jan 7;362(1):18-26.
- Digison MB. 'A review of anti-septic agents for pre-operative skin preparation.' *Plast Surg Nurs*. 2007 Oct-Dec;27(4):185-9; quiz 190-1. Review.
- Ellenhorn JD, Smith DD, Schwarz RE, Kawachi MH, Wilson TG, McGonigle KF, Wagman LD, Paz IB. 'Paint-only is equivalent to scrub-and-paint in preoperative preparation of abdominal surgery sites.' *J Am Coll Surg*. 2005 Nov;201(5):737-41.
- Farrington RM, Rabindran J, Crocker G, Ali R, Pollard N, Dalton HR. 'Bare below the elbows' and quality of hand washing: a randomised comparison study. *J Hosp Infect*. 2010 Jan;74(1):86-8. Epub 2009 Nov 20.
- Frabetti A, Vandini A, Balboni P, Triolo F, Mazzacane S. 'Experimental evaluation of the efficacy of sanitation procedures in operating rooms.' *Am J Infect Control*. 2009 Oct;37(8):658-64.
- Gardella C, Goltra LB, Laschansky E, Drolette L, Magaret A, Chadwick HS, Eschenbach D. 'High-concentration supplemental perioperative oxygen to reduce the incidence of postcesarean surgical site infection: a randomized controlled trial.' *Obstet Gynecol*. 2008 Sep;112(3):545-52.
- Grant J, Ramman-Haddad L, Dendukuri N, Libman MD. 'The role of gowns in preventing nosocomial transmission of methicillin-resistant Staphylococcus aureus (MRSA): gown use in MRSA control.' *Infect Control Hosp Epidemiol*. 2006 Feb;27(2):191-4.
- Greenberg BM, Williams MA. 'Infectious complications of temporary spinal catheter insertion for diagnosis of adult hydrocephalus and idiopathic intracranial hypertension.' *Neurosurgery*. 2008 Feb;62(2):431-5; discussion 435-6.
- Greif R, Akça O, Horn EP, Kurz A, Sessler DI. 'Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection. Outcomes Research Group.' *N Engl J Med*. 2000 Jan 20;342(3):161-7.
- Guzel A, Ozekinci T, Ozkan U, Celik Y, Ceviz A, Belen D. 'Evaluation of the skin flora after chlorhexidine and povidone-iodine preparation in neurosurgical practice.' *Surg Neurol*. 2009 Feb;71(2):207-10;.

References

- Henschen A, Olson L. 'Chlorhexidine-induced degeneration of adrenergic nerves.' *Acta Neuropathol.* 1984;63(1):18-23.
- Hunt TK, Hopf HW. 'High inspired oxygen fraction and surgical site infection.' *JAMA.* 2009 Oct 14;302(14):1588-9.
- Jiang J, Wu M, Shen T. 'The toxic effect of different concentrations of povidone iodine on the rabbit's cornea.' *Cutan Ocul Toxicol.* 2009;28(3):119-24.
- Jurkovich P. 'Home- versus hospital-laundered scrubs: a pilot study.' *MCN Am J Matern Child Nurs.* 2004 Mar-Apr;29(2):106-10.
- Meyhoff CS, Wetterslev J, Jorgensen LN, Henneberg SW, Høgdall C, Lundvall L, Svendsen PE, Mollerup H, Lunn TH, Simonsen I, Martinsen KR, Pulawska T, Bundgaard L, Bugge L, Hansen EG, Riber C, Gocht-Jensen P, Walker LR, Bendtsen A, Johansson G, Skovgaard N, Heltø K, Poukinski A, Korshin A, Walli A, Bulut M, Carlsson PS, Rodt SA, Lundbech LB, Rask H, Buch N, Perdawid SK, Reza J, Jensen KV, Carlsen CG, Jensen FS, Rasmussen LS; PROXI Trial Group. 'Effect of high perioperative oxygen fraction on surgical site infection and pulmonary complications after abdominal surgery: the PROXI randomized clinical trial.' *JAMA.* 2009 Oct 14;302(14):1543-50.
- Miller JJ, Weber PC, Patel S, Ramey J. 'Intracranial surgery: to shave or not to shave?' *Otol Neurotol.* 2001 Nov;22(6):908-11.
- Parienti JJ, Thibon P, Heller, R, et. al. 'Hand-Rubbing With an Aqueous Alcoholic Solution vs Traditional Surgical Hand-Scrubbing and 30-Day Surgical Site Infection Rates: A Randomized Equivalence Study.' *JAMA.* 2002 August; 288(6): 277-727.
- Pearce BA, Miller LH, Martin MA, Roush DL. 'Efficacy of clean v sterile surgical prep kits.' *AORN J.* 1997 Sep;66(3):464-70.
- Procter LD, Davenport DL, Bernard AC, Zwischenberger JB. 'General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay.' *J Am Coll Surg.* 2010 Jan;210(1):60-5.e1-2.
- Safdar N, Marx J, Meyer NA, Maki DG. 'Effectiveness of preemptive barrier precautions in controlling nosocomial colonization and infection by methicillin-resistant *Staphylococcus aureus* in a burn unit.' *Am J Infect Control.* 2006 Oct;34(8):476-83.
- Shapiro JM, Bond EL, Garman JK. 'Use of a chlorhexidine dressing to reduce microbial colonization of epidural catheters.' *Anesthesiology.* 1990 Oct;73(4):625-31.
- Siddique MS, Matai V, Sutcliffe JC. 'The preoperative skin shave in neurosurgery: is it justified?' *Br J Neurosurg.* 1998 Apr;12(2):131-5.
- Snyder GM, Thom KA, Furuno JP, Perencevich EN, Roghmann MC, Strauss SM, Netzer G, Harris AD. 'Detection of methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci on the gowns and gloves of healthcare workers.' *Infect Control Hosp Epidemiol.* 2008 Jul;29(7):583-9.
- Springer R. 'Laundering scrubs.' *Plast Surg Nurs.* 2008 Jan-Mar;28(1):45-6.
- Tokimura H, Tajitsu K, Tsuchiya M, Yamahata H, Taniguchi A, Takayama K, Kaji M, Hirabaru M, Hirayama T, Shinsato T, Arita K. 'Cranial surgery without head shaving.' *J Craniomaxillofac Surg.* 2009 Dec;37(8):477-80.
- Tanner J, Swarbrook S, Stuart J. 'Surgical hand antisepsis to reduce surgical site infection.' *Cochrane Database Syst Rev.* 2008 Jan 23;(1):CD004288. Review.
- Tang K, Yeh JS, Sgouros S. 'The Influence of hair shave on the infection rate in neurosurgery. A prospective study.' *Pediatr Neurosurg.* 2001 Jul;35(1):13-7.

Thank You!