1. Summary of the Scientific Report

SNSF Project Grant 179500: **Understanding the drivers of surgical site infection: Investigating and modeling the Swissnoso surveillance data**

Jonas Marschall, December 12, 2022

This project proposed to investigate the national surveillance data on surgical site infections (SSI) and enrich this dataset with additional information in order to allow correlation analyses. Originally, 3 aims with overall 5 objectives were formulated. First, a descriptive epidemiological study of SSI in Switzerland. Second, correlational analyses of SSI rates with A) surveillance thoroughness, B) operating room ventilation, and C) the operating room personnel's subjective safety climate. Third, a mathematical model of SSI pathogenesis. For this purpose, we assembled a large team that consists of medical doctors, nurses, statisticians, ventilation engineers, patient safety specialists, and a physicist with expertise in modeling.

The milestones could be largely kept as planned, with the exception of a delay caused by 1) the Covid-19 pandemic when the PI had to assume greater responsibilities for countermeasures in his hospital, and 2) the maternity leave of one research team member. Due to these two factors, we had to ask for an extension by 3 months. The total running time was therefore 51 months.

The research team also remained stable over the funding period but was expanded as needed for several aims.

Aim 1 required an analysis into risk factors for SSI. Initially, we focused on SSI that occurred following the patient discharge from the hospital. These infection turned out not be significantly different from those identified during the index hospital stay; this analysis led to the first presentation of results, which was during the international conference IDweek in San Francisco 2018. Following this, we focused on the follow-up period of surveillance, which was – compared to surveillance systems in other countries – relatively long for procedures such as joint replacement and cardiac surgery. We were able to characterize the share of SSI identified in relation to the duration of observation, and this curve showed a yield that quickly became small. In the figure below this can be appreciated (excerpt from Piezzi et al, Infect Control Hosp Epidemiol 2022).

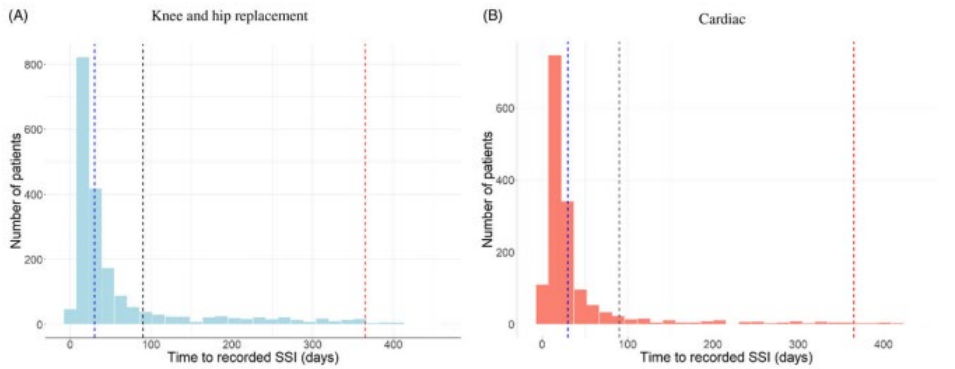
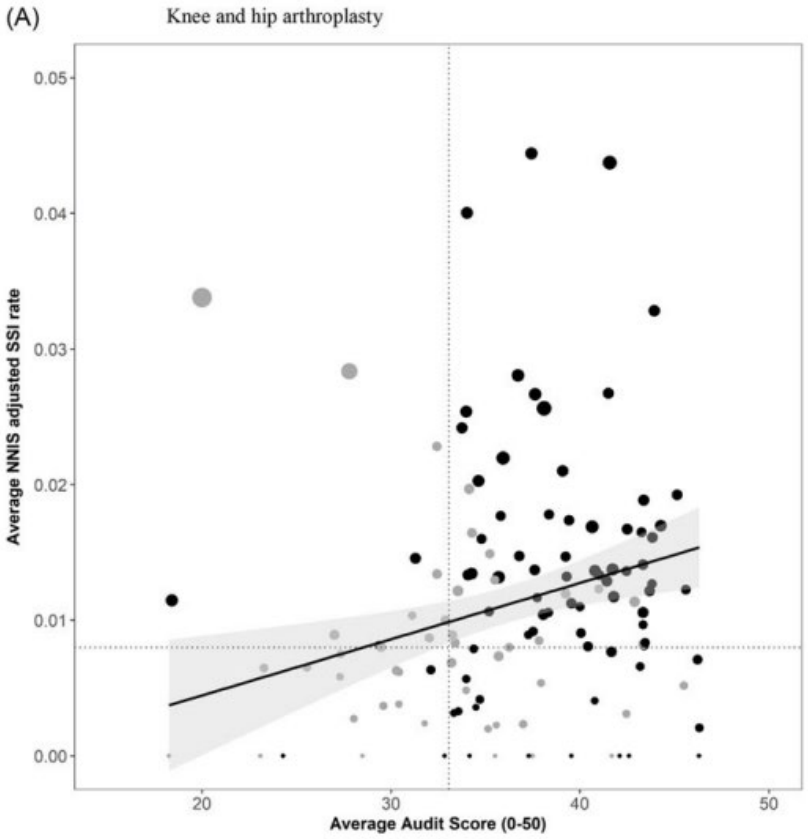


Fig. 1. Distribution of time to recorded SSI from date of procedure for hip and knee replacement (left panel) and cardiac (right) surgeries with cutoffs at 30 days (blue dashed), 90 days (black dashed line), and 365 days (red dashed line). Note. SSI, surgical site infection. A. Knee and hip replacement B. Cardiac

This work helped the National Center of Infection Control, Swissnoso, to eventually adapt their follow-up period of surveillance to that of other countries. As of now, the SSI surveillance data is therefore easier to compare to international data.

A further exploration into the risk factors for SSI brought us to analyze the effect of seasonality on SSIs. We found that – for joint replacement – the summer months are associated with the greatest risk of SSI. This has been reported from other countries before, yet never with the granularity of data that our analysis provided. A manuscript is currently in preparation (Damonti et al).

In Aim 2A, we wanted to better understand what the effect of the quality of the surveillance is on the detection of SSIs. The hypothesis was that a more thorough surveillance will result in more SSI being identified; accordingly, those hospitals that do a good job in their surveillance activities are "punished" by higher SSI rates, and vice versa. For this analysis, we used the audit scores that Swissnoso had assembled based on a number of characteristics of the surveillance process. Indeed, this correlation revealed what we had suspected (please see figure below, from Atkinson et al, Infect Control Hosp Epidemiol 2021). The black dots in this figure (on joint replacement surgery) are public hospitals and the grey ones private. There is an apparent clustering of better surveillance / higher SSI rate hospitals in the upper right field and they are more likely to be public hospitals.



Aim 2B was another correlation, SSI rates and their link to the operating room ventilation. For this purpose, we worked with ventilation engineers and came up with a novel ventilation index that describes the quality of ventilation. We obtained information on roughly 50 hospitals and 180 operating rooms. When we did the analysis, the quality of the operating room ventilation appeared to matter in certain surgeries (cardiac, joint replacement) but not in others (abdominal surgery). Previously, operating room ventilation was mostly described in a simple dichotomy based on the typo of flow. With our ventilation index, we have produced a straightforward tool that should be validated in further studies. Figure 3 below indicates where the ventilation mattered and where not. Surial et al, Annn Surgery 2022.

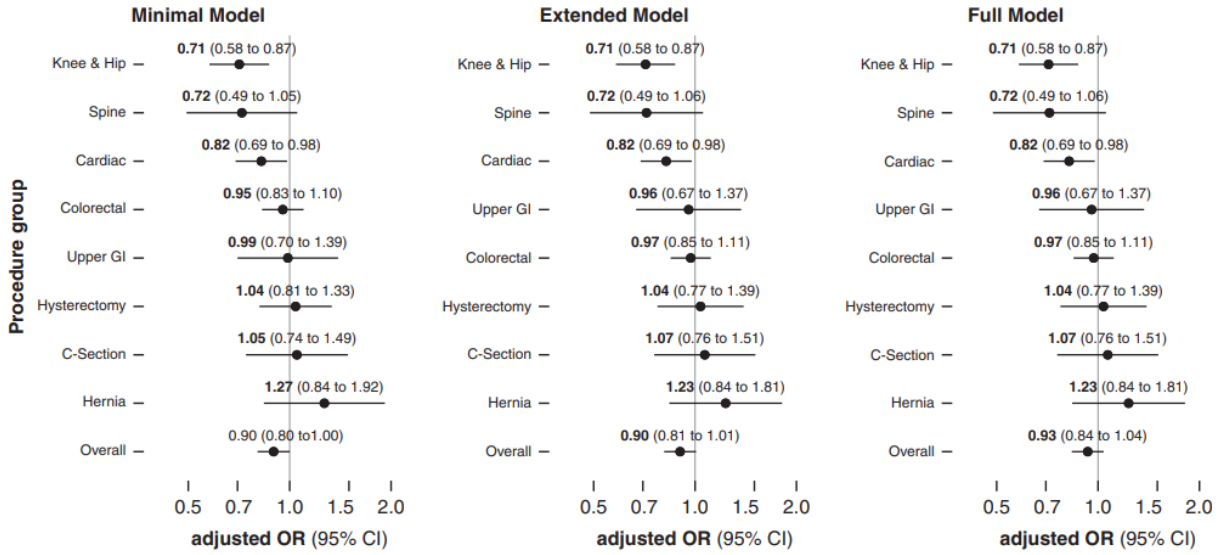
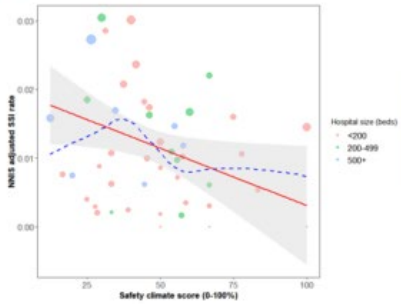


FIGURE 3. Patient-level analysis assessing the odds ratios of surgical site infections, overall and stratified by surgery type, per 5 units increase in ventilation index. The minimal model is adjusted for all components of the National Nosocomial Infections Surveillance (NNIS) risk index, and the intervention type. The extended model includes the same covariates as the minimal model, and additionally elective versus urgent surgery, adequate timing of antibiotic prophylaxis (within 120 minutes for fluoroquinolones and vancomycin, and within 60 minutes for other antibiotics), age, and sex. The full model includes all covariates, including hospital size and type (public, private, and university). CI indicates confidence interval; C-section, cesarean section; GI, gastrointestinal; OR, odds ratio.

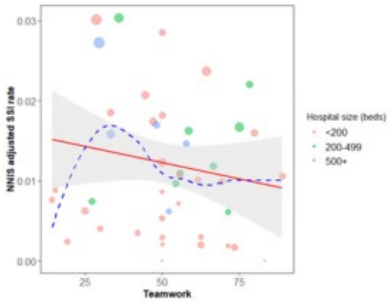
Aim 2C is an investigation into the subjective safety climate of operating room personnel. Here, we sent out surveys to 54 hospitals and received responses from 2769 healthcare workers. In a first manuscript, which is under review, we describe the safety climate among these teams (Pfeiffer et al, J Pat Safety). In the second manuscript, we attempted to correlate the resulting “safety climate score” with SSI rates from these hospitals (Pfeiffer et al, BMJ Open). The implicit hypothesis was that a greater awareness for the importance of patient safety will translate into fewer healthcare –associated infections. As the figure below indicates there were trends in this direction, however, none of them significant.

A. Knee and hip arthroplasty

i. Safety climate



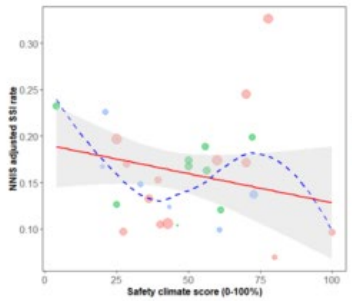
ii. Teamwork



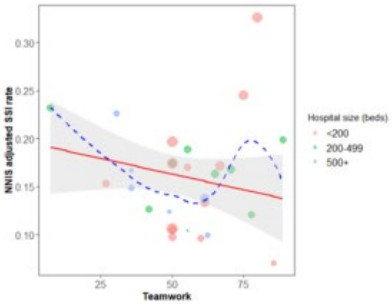
NHSN: National Healthcare Safety Network

B. Colorectal surgery

i. Safety climate



ii. Teamwork



Aim 3, finally, was intended to help build a mathematical model of SSI pathogenesis, in order to simulate historic, current, or envisioned interventions and their effect on national SSI rates. In this aim, we have successfully constructed such a model and validated it with the actual Swissnoso data. We are currently preparing a manuscript (Salazar-Vizcaya et al). Briefly, this model has allowed us to predict what preventive measures would have the greatest effect if rolled out across the country. One of them, to give an example, is the dual intravenous and oral antibiotic prophylaxis in colon surgery.

In summary, all the aims have been addressed as planned. No major deviations occurred. Out of 5 original objectives, 3 have been published in peer-reviewed journals. Four more are in preparation, for a total output of 7 articles. All of the research staff and collaborators took part in the design, data acquisition, analysis, and interpretation of the findings. In addition to the original research team, additional members were added over time and provided significant contributions (Vanja Piezzi, Philipp Jent, Lauro Damonti, Bernard Surial, Ruediger Kuelpmann, Arnold Brunner). We consider this project to be a successful collaborative with a number of partner institutions, including but not limited to the University of Bern, Institute of Social and Preventive Medicine (Marcel Zwahlen), the Lucerne University of Applied Sciences and Arts (Benoit Sicre, Ruediger Kuelpmann, and others), and Patient Safety Switzerland (David Schwappach, Yvonne Pfeiffer).

We thank the SNSF for the opportunity to conduct research under this funding mechanism. From our perspective, this has been an extraordinarily productive research endeavor.

2. Research Output

Watussi - overview published and planned manuscripts, November 2022			
Aim	**Project**	**Authors**	**Current state**
1	Focusing on the follow-up for detecting surgical site infections after total joint arthroplasty and cardiac surgery: A cohort study from the Swiss national surveillance system, 2009-2018.	V. Piezzi, A. Atkinson, P. Jent, N. Troillet, M. Zwahlen, A. Widmer, J. Marschall	Infect Control Hosp Epidemiol. 2022 May 5:1-2. doi: 10.1017/ice.2022.77.
1	Influence of environmental temperature and heatwaves on surgical site infection after hip and knee arthroplasty: a nationwide study	L. Damonti, A. Atkinson, L. Fontannaz, J. P. Burnham, N. Troillet, A. Widmer, J. Marschall	In progress
2A	Surveillance quality correlates with surgical site infection rates in knee and hip arthroplasty and colorectal surgeries: a call to action to adjust reporting of SSI rates	A. Atkinson, M.-C. Eisenring, N. Troillet, A. Widmer, M. Zwahlen, J. Marschall	Infect Control Hosp Epidemiol. 2021 Feb 18:1-7. doi: 10.1017/ice.2021.14
2B	Better Operating Room Ventilation as Determined by a Novel Ventilation Index is Associated With Lower Rates of Surgical Site Infections	B. Surial, A. Atkinson, R. Külpmann, A. Brunner, K. Hildebrand, B. Sicre, N.Troillet, A. Widmer, E. Rolli, J. Maag, J. Marschall	Ann Surg. 2022 Nov 1;276(5):e353-e360. doi: 10.1097/SLA.0000000000005670. Epub 2022 Aug 10.
2C	Are surgical site infection rates associated with safety climate as assessed in a survey of operation room staff?	Y. Pfeiffer, A. Atkinson, J. Maag, M. Lane, D. Schwappach, J. Marschall	BMJ Open, resubmitted in November 2022
2C	Preventing surgical site infections (SSI): Are safety climate level and its strength associated with self-reported commitment to, subjective norms towards, and knowledge about preventive measures?"	Y. Pfeiffer, A. Atkinson, J. Maag, M. Lane, D. Schwappach (co-last author), J. Marschall (co-last author)	Journal of Patient Safety, accepted pending minor revision
3	To what extent can colorectal surgical site infections be prevented? An individual-based modelling study	L. Salazar, A. Atkinson, M. Zwahlen, J. Marschall	In progress

Related projects			
	Cefuroxime plus metronidazole vs. amoxicillin/clavulanic acid as antibiotic prophylaxis in colorectal surgery	E. Stavropoulou, A. Atkinson, M.-C. Eisenring, J. Marschall, Ch. A. Fux, N. Troillet	Abstract and poster presentation ICPIC 2021, manuscript in preparation
	Perioperative antibiotic prophylaxis in paediatric appendectomies in Switzerland	H. Schmid, J. Bielicki, N. Troillet, others	In progress
	Antimicrobial prophylaxis administration after umbilical cord clamping in cesarean section and the risk of surgical site infection: a cohort study with 55,901 patients	R. Sommerstein, J. Marschall, A. Atkinson, D. Surbek, M.G. Dominguez-Bello, N. Troillet, A.F. Widmer; Swissnoso.	Antimicrob Resist Infect Control. 2020 Dec 22;9(1):201. doi: 10.1186/s13756-020-00860-0.
	Association Between Antimicrobial Prophylaxis With Double-Dose Cefuroxime and Surgical Site Infections in Patients Weighing 80 kg or More.	R. Sommerstein, A. Atkinson, S.P. Kuster, D. Vuichard-Gysin, S. Harbarth, N. Troillet, A.F. Widmer, Swissnoso Network	JAMA Netw Open. 2021 Dec 1;4(12):e2138926. doi: 10.1001/jamanetworkopen.2021.38926.
	Prevention of surgical site infection in hip and knee prosthesis implantation: Are cefazolin and cefuroxime equally effective?	M. Kalubi, A. Atkinson, K. Damonti, J. Marschall, Ph. Jent	In progress
	Association between the choice of surgical antimicrobial prophylactic regimen and risk of surgical site infection after hysterectomy: a prospective surveillance study	D. Vuichard, D. Berthod, J. Marschall, A. Widmer, others	In progress