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Individual hand hygiene improvements and effects on healthcare-associated infections: a long-term follow-up study using an electronic hand hygiene monitoring system

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S U M M A R Y

Background: Obtaining detailed insights into people's unique hand hygiene behaviour could play an important role in developing the most effective long-term hand hygiene compliance (HHC) interventions.
Aim: To investigate the effect of two feedback interventions provided by an electronic hand hygiene monitoring system (EHHMS) on sustained HHC improvement, individual responsiveness, and prevention of hospital-acquired bloodstream infections (HABSIs) and urinary tract infections (HAUTIs).
Methods: The study included two 2-year cohorts (exposed and unexposed to EHHMS) observed over 4 years in an internal medicine department with 142 caregivers and 39 doctors. Healthcare workers (HCWs) were stratified into four groups based on their baseline performance to assess predicted responsiveness to the interventions.
Findings: All HCWs increased their HHC independently from their performance at baseline, except for a few in the low-performance groups with constantly low HHC. The two low-performance groups at baseline were most responsive to group feedback (weekly change in HHC of 4.4% and 3.1%) compared with individual feedback (weekly change in HHC of 1.0% and 2.2%). The number of cases of HABSI reduced significantly during the intervention period (P=0.01), with the greatest effect on *Staphylococcus aureus*. No significant change in HAUTIs was observed.
Conclusion: The EHHMS interventions sustained the HHC improvements successfully and reduced the number of cases of HABSI. Nearly all HCWs responded to the interventions. The two low-performance groups at baseline never reached the same HHC levels as those in the high-performance groups, indicating the potential for further improvement and the need for intensified individualized interventions.

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Introduction

Hospital-acquired infections (HAIs) affect 6–8% of hospitalized patients in Europe [1]. Proximity to other patients and frequency of healthcare worker (HCW) contact promote the transmission of pathogens, including multi-drug-resistant micro-organisms [2]. Hand hygiene (HH) is essential in preventing cross-transmission. Therefore, the World Health Organization (WHO) strongly recommends HH compliance (HHC) as a key performance indicator in all countries, and recommends that training should be based on the local HHC results to measure the progress of HH programmes [3]. However, most infection prevention and control (IPC) teams do not have the time to manually collect a sufficient sample size to detect true changes in HHC over time for all wards, including nights and weekends.

To meet these challenges, WHO encourages innovations, such as electronic HH monitoring systems (EHHMSs) [3]. An EHHMS addresses several of the concerns of traditional methods, as it allows for observation at all times while eliminating potential observation and observer biases [4].

Although widely promoted, average HHC is 52% for nurses and 45% for doctors with manual observation [5], and challenges remain to sustain the improvements achieved from interventions [6].

Previously, the authors have reported the results from the first European study to investigate the association between HHC improvements and hospital-acquired bloodstream infections (HABSIs) using an EHHMS [7]. Both doctors and caregivers improved their HHC significantly during the coronavirus disease 2019 (COVID-19) pandemic using data from the EHHMS, and the improvement was associated with a significant reduction in HABSIs. However, there is still a need to identify the most effective long-term interventions and document the associated changes in HAIs. In particular, more individual response data are needed to determine the facilitators and barriers to interventions that can help personalize the approaches. However, only a few studies have reported individual responses to different interventions [8–14].

As such, this study aimed to examine the effects of two types of HH feedback interventions provided by an EHHMS to achieve sustained improvements and prevent HABSIs and hospital-acquired urinary tract infections (HAUTIs). In addition, individual responses to the interventions were investigated in order to understand the underlying behavioural dynamics.

Methods

Study design and setting

A long-term follow-up study was conducted to investigate the sustained effects of the interventions on individual HHC and the prevalence of HABSIs and HAUTIs. Two HH interventions were tested in a European inpatient nephrology department: a group feedback improvement strategy, and an individual feedback improvement strategy, as described previously [7].

After a baseline period of 3 months with HHC measurements, the HCWs were exposed to HH insights provided by the EHHMS. Initially, an improvement strategy based on group feedback was tested during the first 5 months of the intervention period. In brief, the EHHMS data were presented at staff meetings (education sessions) twice each month by local hygiene mentors (champions), in newsletters and on bulletin boards. Focused feedback was given on the areas with low HHC and followed a three-step process: (1) summary of the results from the previous weeks to generate awareness and to ensure continuous follow-up; (2) open discussion to facilitate knowledge distribution; and (3) guided practice to focus on the most relevant areas for improvement.

An individual feedback improvement strategy was added for the remaining part of the study period to see whether HHC could be sustained or further improved. In brief, HCWs were encouraged to obtain their own individual data via weekly emailed reports, showing when and where improvements were below target and how the staff member performed compared with the rest of the team. At the same time, the local hygiene mentors encouraged the HCWs to share their results and ask their hygiene mentor for support whenever they felt it was difficult to reach the targets.

Study participants

Doctors and caregivers were eligible if they had regular patient contact and were willing to keep an anonymous sensor affixed to their nametag throughout the study period. All eligible staff members accepted to participate.

The electronic hand hygiene monitoring system

Data from a 4-year period were used in this study. The first 2 years (July 2018–June 2020) served as a historical control for the incidence of HAI. Once the EHHMS was implemented, a baseline period was introduced (February 2020–June 2020) to investigate HHC levels with no ongoing HH efforts. In practice, the EHHMS only collected data for 3 months during the baseline because it was interrupted for 2 months due to the COVID-19 pandemic (the department relocated temporarily). The baseline period was followed by 2 years with HH interventions (July 2020–June 2022).

This study focused on alcohol-based hand rub (ABHR) based on the WHO's 'My 5 Moments for Hand Hygiene', and collected the data using an EHHMS (Sani Nudge) that has been described in detail elsewhere [7]. In brief, the HCWs attached an anonymous sensor to their nametag, from where it collected and shared each HH opportunity by connecting to dispenser sensors and sensors at patient beds. The patient bed sensors identified if the HCWs had patient contact (proxy based on time and distance algorithms), and the dispenser sensors identified if the HCWs sanitized before and after contact. Sensors were also placed on walls in work areas, such as medication rooms, utility rooms and staff toilets, to measure HH opportunities in these places when entering or leaving the particular room. The decision was made not to measure the use of soap (handwash), although the EHMMS can do so, because the national hygiene guidelines for HCWs state that handwashing must always be followed by ABHR, making the hand registrations in this study unnecessary. Data were collected via a cloud-based solution, and processed results were presented via an online platform and emails. Data presentation leveraged on nudge theory to make data easy to understand and actionable. The focus was to empower the HCWs and guide them to make correct HH decisions in the moment.

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Classification of HABSI and HAUTI

BSI was defined as the presence of a significant pathogen in the blood and the prescription of an appropriate concomitant antimicrobial treatment. UTI was defined as growth ($\geq 10^4$ colony-forming units/mL) of a significant pathogen in urine samples obtained from patients with symptoms of UTI (dysuria, urinary frequency, urgency and/or suprapubic pain) and prescribed an appropriate concomitant antimicrobial treatment. Species accepted as significant pathogens for HAUTIs included *Escherichia coli* and other Enterobacterales.

Data were retrieved from an electronic monitoring system [15] and classified as hospital-acquired if patients had been hospitalized for >48 h at the time of a positive blood or urine culture. The authors audited the classification of the cases manually by reviewing the electronic medical records.

Ethics

Participation was voluntary. The Hospital Review Board approved the study (No. 21/478).

Statistical analysis

Continuous variables were reported as mean with standard deviation or 95% confidence interval (CI). The Shapiro–Wilk normality test confirmed the parametric distribution of data. Differences between HHC means were assessed using Student's *t*-test. In order to investigate if HH behaviour at the beginning of the study predicted responsiveness to the interventions, a subgroup analysis of HCWs (N=60) was conducted with no interruption in data during the 2 years of EHHMS data collection. The HCWs were divided into four groups (percentiles) based on mean HHC performance during baseline, and their progress was followed over time (Figure 1). Differences in infection incidence rates between the intervention period and the historical control period (preceding 2 years) were assessed using the log-rank test. Two-sided P-values <0.05 were considered to indicate significance. All analyses were performed using GraphPad Prism Version 9.1.0 and STATA Version 16.

Results

The EHHMS registered 181 Sani IDs (142 caregivers and 39 doctors) during the study period. On average, EHHMSs registered 33 caregivers and nine doctors monthly. Analysis of the activity level showed a monthly average of 105 HH opportunities per doctor (range 16–172) and 594 HH opportunities per caregiver (range 111–838). The higher number of HH opportunities for the caregivers was explained by their workflow, with more time in the department, a higher number of patient interactions, and daily tasks in medication rooms and other utility rooms.

Hand hygiene compliance

Caregivers had higher baseline HHC than doctors (40% vs 22%; $P<0.001$), and the difference was sustained throughout the study (Figure 2). Both groups increased their HHC during group feedback and individual feedback compared with baseline.

All HCWs increased their HHC independently from their performance at baseline (Figure 1). In particular, the HCWs with low and moderate–low performance increased their HHC the most when receiving group feedback, but also had the most potential to improve (Table I). This picture changed during the period with individual feedback, where the HCWs with low performance improved less than the other groups. The behavioural pattern also showed that the HCWs with moderate–high performance improved quickly and reached the same levels as those with high baseline performance. When looking further into individual performances, only a few HCWs were less receptive to the interventions, having a constantly low HHC (Figure 3, low and moderate–low baseline).

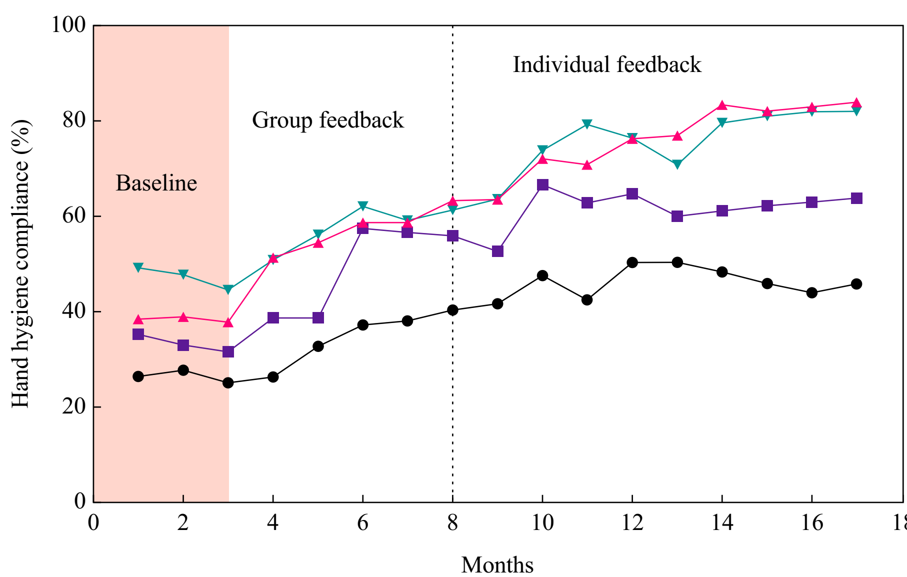

Figure 1. Grouped hand hygiene compliance by baseline performance. Green, high at baseline; red, moderate–high at baseline; purple, moderate–low at baseline; black, low at baseline.

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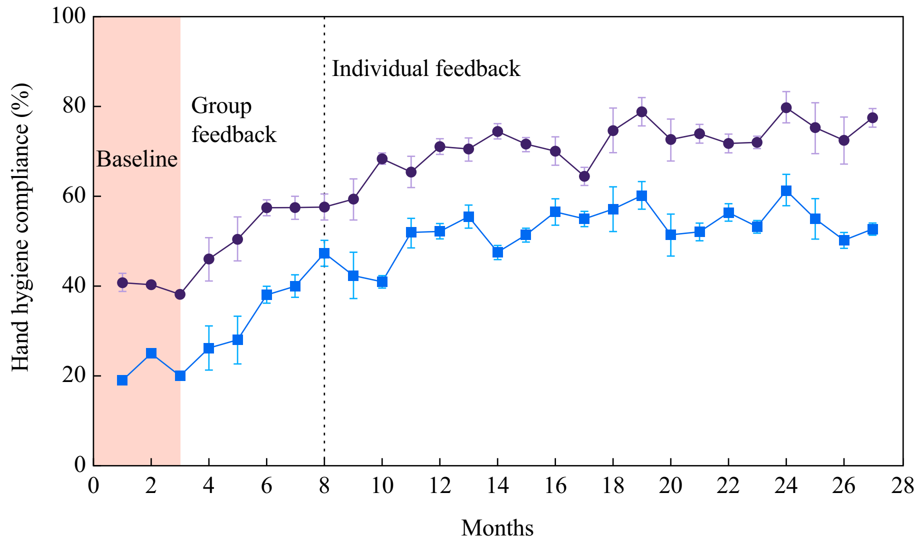

Figure 2. Changes in hand hygiene compliance over time. Purple, caregivers (*N*=142); blue, doctors (*N*=39).

Table I
Effect of interventions on hand hygiene compliance (HHC) by baseline performance level (percentiles of mean)

Low HHC at baseline (*N*=15)		
Period	Average change in weekly HHC	HHC for the period
Baseline	-0.3%	26.1%
Group feedback	4.4%	35.0%
Individual feedback	1.0%	43.7%
Moderate low HHC at baseline (*N*=15)		
Period	Average change in weekly HHC	HHC for the period
Baseline	-1.4%	32.5%
Group feedback	3.1%	48.8%
Individual feedback	2.2%	60.5%
Moderate high HHC at baseline (*N*=15)		
Period	Average change in weekly HHC	HHC for the period
Baseline	1.1%	38.2%
Group feedback	2.6%	56.4%
Individual feedback	3.5%	71.7%
High HHC at baseline (*N*=15)		
Period	Average change in weekly HHC	HHC for the period
Baseline	-0.7%	46.2%
Group feedback	2.4%	57.4%
Individual feedback	1.6%	70.5%

Hospital-acquired infections

Patient characteristics were comparable during the historical control period and intervention period (Figure S1, see online supplementary material). The number of cases of HABSI was reduced significantly during the intervention period to four cases per 10,000 patient-days (95% CI 2–11) compared with 14 cases per 10,000 patient-days (95% CI 9–21) during the control period, with an incidence rate difference of -9 per 10,000 patient-days (95% CI -16 to -2; P=0.01). The number of cases of HAUTI was slightly lower during the intervention period (35 per 10,000 patient-days, 95% CI 22–42) than the control period (36 per 10,000 days, 95% CI 28–47) but with no significant incidence rate difference (-1 per 10,000 patient-days, 95% CI -16 to 14; P=0.89). Table II shows the distribution of species causing HABSIs and HAUTIs.

Discussion

The feedback interventions provided by the EHHMS were a success. Both doctors and caregivers achieved sustained HHC improvements, associated with a significant reduction in HABSIs and a non-significant reduction in HAUTIs. Importantly, the overall improvements in HHC at ward level were driven by a collective effort and not by a few high performers. Only a few

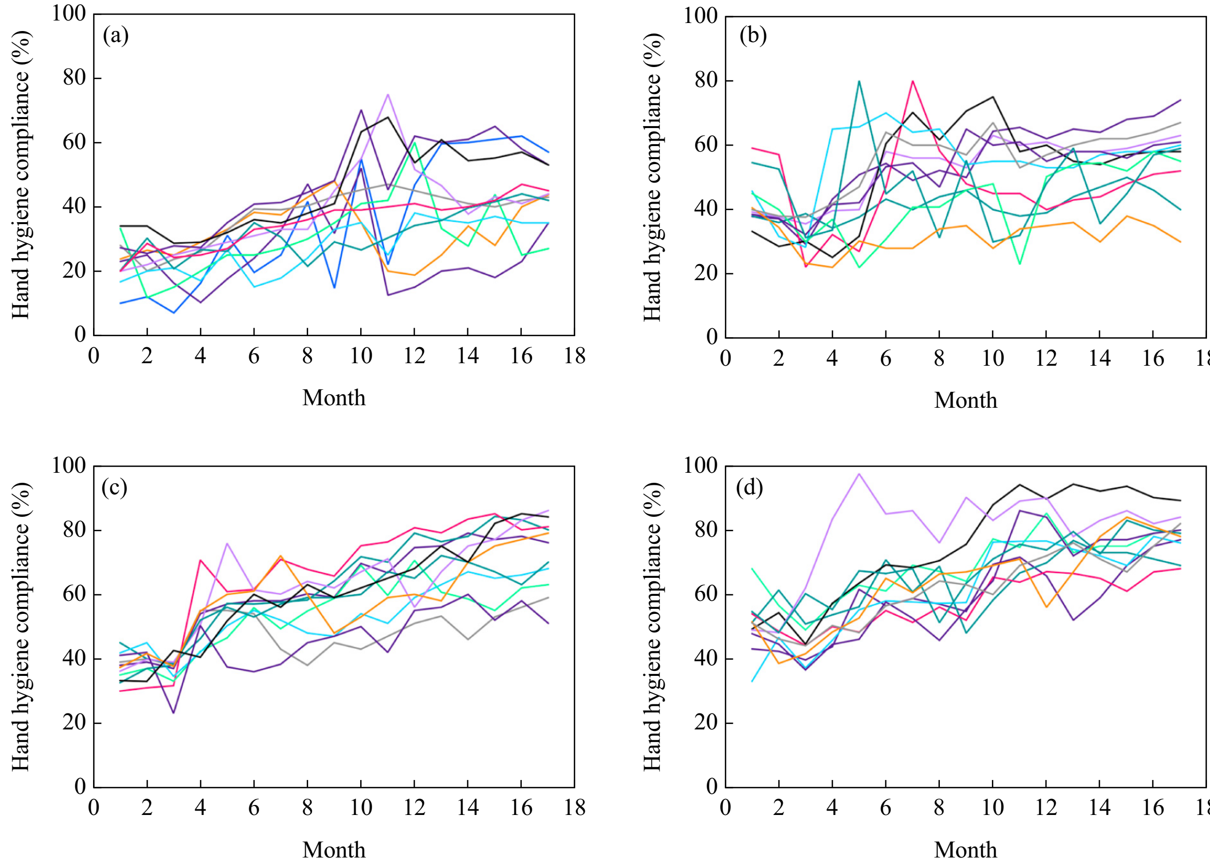

Figure 3. Individual hand hygiene compliance by baseline performance. (a) Low at baseline; (b) moderate—low at baseline; (c) moderate—high at baseline; (d) high at baseline.

HCWs in the low and moderate—low baseline groups were less receptive to the interventions, and had constantly low HHC throughout the study (Figure 3). These two low-performance groups at baseline were most responsive to group feedback, but also had the greatest potential for improvement. It could also be that these people learn better during interactions with colleagues rather than from individualized instructions directed to them.

This study is important because it aids understanding of the patterns of individual HHC in response to interventions. The benefits are two-fold: effective improvement efforts can be designed, and training can be personalized according to individual needs. In this study, only a few HCWs did not respond to the interventions, indicating that explanation factors concerned the HCWs individually rather than systemic factors, such as lack of leadership support, inappropriate dispenser placement or an excessive daily workload. Early recognition of individual factors will help IPC teams to customize improvement strategies to people with typical HH patterns where personal beliefs, motivation and workflows play essential roles [16,17]. Qualitative data were not collected systematically in a structured manner in this study, but an example of interaction between the local hygiene mentors and HCWs should be mentioned. Several HCWs had difficulty improving their HHC and asked the local hygiene mentor to observe them in different situations, and provide input as to when and where their HH efforts could improve. The observations revealed some noncompliant HH routines and behaviour. The feedback from the hygiene mentor helped the HCWs to improve their HHC.

Only a few modelling studies have investigated the HHC level needed for HAIs to decline, and found a mean HHC threshold >48%, 66% and 87%, respectively [18—20]. Modelling data can be useful, but real-world data can reveal different findings. The present study found that doctors reached sustained HHC levels >50% and caregivers >70%, associated with a significant reduction in HABSIs. Not only was a clinically relevant reduction achieved, but the incidence of four cases per 10,000 patient-days was below other hospitals in the same region (7.1 cases per 10,000 patient-days) and below the national level (6.5 cases per 10,000 patient-days) [21]. No significant reduction in HAUTIs was found. The large 95% CI could indicate a lack of power. This study was performed in a nephrology department with high risk of HAUTIs, given the nephrological diseases and the high rate of catheter usage. A larger sample size (more events, larger ward, more patients) or an extended study period would be needed to detect a true difference caused by the intervention. However, a slightly lower incidence was found during the intervention period compared with the historical control period, supporting the significant reduction in HABSIs. This study supports the findings of others, emphasizing the considerable potential to reduce the occurrence of HABSIs [22].

Interestingly, *Staphylococcus aureus* was the dominant BSI pathogen (approximately 50%) in the control period, but disappeared as the cause of HABSIs during the intervention period (Table II). As a common skin colonizer, *S. aureus* (a typical exogenous cause of infection) may be more sensitive to

Table II
Distribution of species

Hospital-acquired bloodstream infections				
Distribution species	Control		Intervention	
	No.	(%)	No.	(%)
Staphylococcus aureus	10	(45)	0	(0)
Klebsiella spp.	3	(14)	2	(40)
Escherichia coli	2	(9)	2	(40)
Other Enterobacterales spp.	2	(9)	0	(0)
Candida spp.	2	(9)	0	(0)
Streptococcus spp.	2	(9)	0	(0)
Pseudomonas aeruginosa	1	(5)	1	(20)
Total	22		5	
Hospital-acquired urinary tract infections				
Distribution species	Control		Intervention	
	No.	(%)	No.	(%)
Escherichia coli	32	(56)	19	(50)
Other Enterobacterales spp.	19	(33)	10	(26)
Pseudomonas aeruginosa	1	(2)	3	(8)
Enterococcus faecalis	3	(5)	3	(8)
Aerococcus urinae	1	(2)	0	(0)
Streptococcus agalactiae	1	(2)	3	(8)
Total	57		38	

eradication by ABHR than Gram-negative rods from the gut flora, which are the primary cause of UTIs (endogenous source). These findings may explain the lesser effect of increased HHC on HAUTIs compared with HABSIs in this study.

Some limitations should be addressed. First, this was a small-scale study, but considerable HH data were collected using the EHHMS, increasing the statistical power of the HHC analyses. The design of the study only allowed the authors to draw conclusions on the combined effects of the EHHMS interventions, and not the effectiveness of group vs individual feedback. Second, the observational nature of this study limited the authors' ability to control for unknown confounders that could influence the reduction in HAIs. However, the study involved two 2-year cohorts (exposed and unexposed to EHHMS) observed over 4 years in one ward, which made it easy to ensure that no substantial changes were made to the IPC procedures and standards during the study period other than the interventions. Third, some of the observed variability in the individual HHC levels could be explained by chance findings due to a limited number of data points collected compared with the grouped analyses. However, an EHHMS and an extended study period were used to increase the number of data points per HCW, which is a limitation of large-scale studies using the direct observation method [14]. Fourth, some HCWs stopped working in the department during the study period, and new staff members started. All of them were included, which could have impacted the overall HHC levels in either direction. However, the individual HHC levels allowed for detailed analyses of the development over time. Fifth, HH opportunities were not measured outside the patient zones, clean zones in staff toilets, medication rooms, and clean and unclean utility rooms. Thus, HH opportunities in other departmental rooms related to patient interactions were not obtained. The EHHMS should be used to look at trends and changes, identify low-performance departments and staff groups to initiate educational actions, measure the effects of different interventions, automate audits by collecting the required number of HH opportunities for reporting bodies, and provide each HCW with insights to their HH behaviour to identify blind spots. Importantly, the EHHMS has shown high sensitivity for detecting HH opportunities for nurses and doctors in previous clinical validation studies [23,24].

In conclusion, the EHHMS interventions sustained the HHC improvements successfully and reduced the HAIs. The majority of HCWs responded to the interventions. The two low-performance groups at baseline never reached the same HHC levels as those in the high-performance groups, indicating a potential for further improvement and the need for intensified individualized interventions. Collecting individual HHC data helped to advance understanding of HH behaviour, and will help in the design of effective interventions that work on as many HCWs as possible.

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Conflict of interest statement

MBH is employed by Konduto ApS, which developed Sani Nudge. The other authors declare that they have no competing interests. All authors approved the final article.

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Appendix A. Supplementary data

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