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Original Research Article

Feedback of ATP measurement as a tool for reducing environmental contamination in hospitals in the Dutch/Belgian border area

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Abstract

Design: A two-phase prospective intervention study.

Objective: The objective of this study was to determine if feedback of adenosine triphosphate (ATP) measurements decreases environmental contamination within hospitals in the Dutch/Belgian border area.

Methods: Standardized ATP measurements were conducted in nine hospitals on pre-defined fomites. Four different fomite groups were defined: medical devices, patient-bound materials, ward-bound materials and sanitary items. ATP results were reported in relative light unit (RLU), RLU >1000 was considered as 'not clean.' Two rounds of ATP measurements were conducted. After the first round of ATP measurements, results were provided to the wards and cleaning staff. The second round of ATP measurements was performed one year later. The amount of surface contamination before and after the feedback was compared.

Results: In total 1923 ATP measurements were performed. Before feedback 960 ATP measurements were conducted and after feedback 963 were conducted. The overall median reduction in RLU was 381 ($P < 0.001$), from 568 before feedback to 187 afterward. In each hospital there was a reduction of the median RLU after feedback.

Conclusions: Substantial reductions in RLU values were found after feedback of ATP measurements. Feedback of ATP measurement in itself was associated with a major reduction of surface contamination in hospitals.

Key words: health-care quality improvement, infection control, nosocomial infections, performance measures

Introduction

Measurement of cleanliness of hospital surfaces tends to be subjective and is often not performed in a standardized way. Measurements are mostly conducted by visual inspection. However, visual inspection is subjective and not very sensitive [1–4]. Environmental contamination can be quantified by

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the measurement of adenosine triphosphate (ATP), a molecule which is present in all organic matter. The amount of ATP can be measured by a luminescence reader and is expressed in relative light unit (RLU), which correlates with the amount of organic matter in the sample [5].

ATP measurements give a direct feedback on surface contamination, while other methods such as measuring aerobic colony count tend to take more time before a result is produced. The direct feedback of ATP measurements can be used to improve cleaning in general or identify problem areas where cleaning is suboptimal [6, 7]. The rapid availability of objective and meaningful data offer a promising alternative for the measurement of cleanliness and can give starting points for the improvement of cleaning. By setting up new (small) cleaning implementations, cleanliness of hospital surfaces can be improved [1, 8]. The objective of this study was to determine if feedback of ATP measurements decreases the level of environmental contamination in hospitals in the Dutch/Belgian border area.

Methods

Setting

As part of a multicenter project in the Dutch/Belgian border area, the i-4-1-Health project, standardized ATP measurements were conducted in nine hospitals (three Belgian university hospitals, one Dutch university hospital, three Dutch teaching hospitals and two Dutch general hospitals). ATP measurements were conducted on different hospital wards, ranging from two to four wards per hospital, depending on the hospital size. In each hospital, ATP measurements were conducted on a surgical ward, an internal medicine ward and if applicable two other medical wards. When ATP measurements were conducted in more than two wards a selection was made from the medical specialties urology, cardiology, orthopedic surgery, pulmonology and/or geriatrics. For the data analysis, medical specialties were merged into two groups: surgical specialties and non-surgical specialties. On each ward, ATP measurements were performed on a selection of 30 pre-defined fomites [9]. These fomites were classified into four different groups: medical devices, patient-bound materials, sanitary items and ward-bound materials. Fomites were chosen based on the following criteria: frequently touched by nursing staff or patients or being in the direct vicinity of patients or high-risk surfaces (e.g. table top for medication preparation). ATP measurements were performed at two points in time, one year apart from each other. In this second round of measurements the same wards and surfaces were measured as in the first round. After the first round of ATP measurements feedback of the results was given to the nursing and cleaning staff by an infection control practitioner. There were no structured cleaning interventions planned. The effect of the feedback in itself was measured in a second round of ATP measurements, cleaning and nursing staff were not notified of the second round of ATP measurements.

ATP measurements and RLU breakpoints

The Clean-Trace NG Luminometer (3M, Zoeterwoude, the Netherlands) was used for the ATP measurements, results were reported in RLU. ATP measurements were conducted by trained and validated researchers working at the department of infection control of the corresponding hospital. The RLU $<$ 1000 breakpoint for cleanliness was defined for measuring a fomite at a random point during the day [9]. An RLU value above 1000 was categorized as unclean or intermediate, above 3000 as dirty.

Statistics

All data were analyzed with Statistical Package for Social Science software (SPSS; IBM Corp., Armonk, New York, USA; version 25) and R (R Foundation, New Zealand, R version 3.6.2). Adjusted relative risks (ARRs) were calculated based on the differences in the occurrence of 'not clean' fomites (RLU $>$ 1000) between the two time periods and analyzed using mixed-effects Poisson regression models using a log link with a random intercept and random slope per hospital. Differences between RLU values were analyzed log transformed using mixed-effects linear regression models with a random intercept and fixed slope per hospital. Adjusted models were corrected for hospital, medical specialty and surface category.

Results

In total 1923 ATP measurements were performed. Before feedback 960 ATP measurements were conducted and after feedback 963 were conducted. Per hospital 120 up to 246 ATP measurements were performed, depending on the hospital size.

The median RLU before feedback was 568 RLU and after feedback 187 RLU, resulting in a reduction of 381 RLU (P $<$ 0.001) (Figure 1). Of all measurements before feedback 37.7% (362/960) were considered as 'not clean' (RLU $>$1000), after feedback 13.1% (126/963) were considered as 'not clean'.

The differences in RLU between the first and second round per hospital are visualized in Figure 2. The median RLU value per hospital before feedback ranged from 279 to 2137. After feedback the median RLU value per hospital ranged from 83 to 830. Each hospital showed a reduction in median RLU between the first and second round of measurements.

Per medical specialty between 60 and 538 ATP measurements were conducted. The median RLU value before feedback was 627 in the surgical specialty group and 546 in the non-surgical specialty group. After feedback, the median RLU value was 200 in the surgical specialty group and 172 in the non-surgical specialty group.

Per fomite group 320 up to 640 ATP measurements were conducted: 627 ATP measurements in the medical devices group, 320 ATP measurements in the patient-bound materials group, 640 ATP measurements in the sanitary items group and 336 ATP measurements in the ward-bound materials group. The differences in RLU between rounds of the fomite groups are visualized in Figure 3. The median RLU value in the patient-bound materials group was reduced from 931 to 224, in the ward-bound materials group from 659 to 293, in the medical devices from 651 to 187 and in the sanitary items from 396 to 131, before and after feedback, respectively.

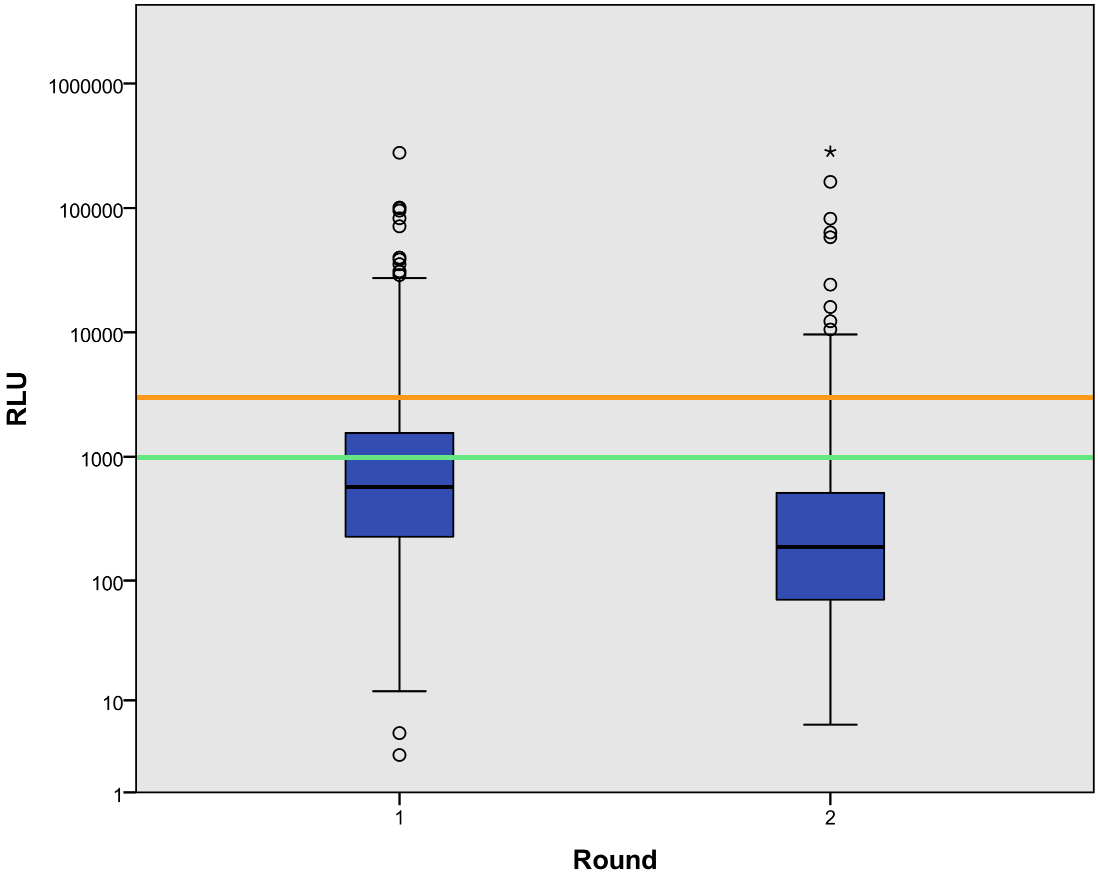

Figure 1 Boxplot of differences between both rounds of measurement. Outliers are marked with a circle, and extreme outliers are marked with a star. RLU breakpoints are marked with colored lines (RLU 1000 and 3000).

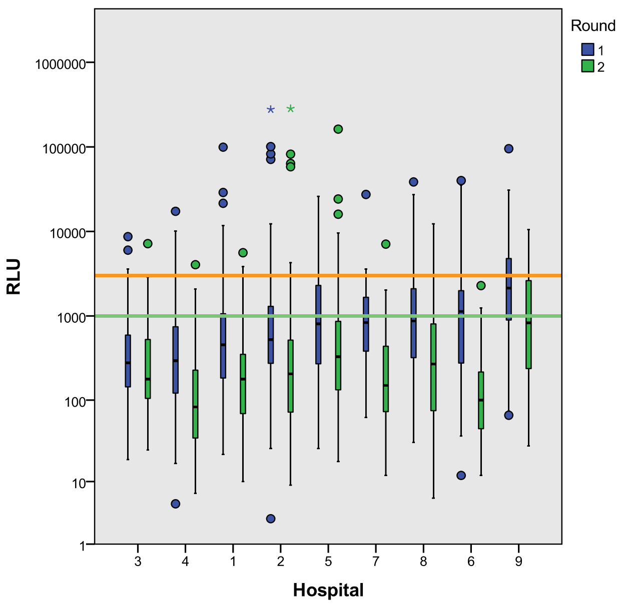

Figure 2 Boxplot of RLU values between hospitals for each round of measurement. Outliers are marked with a circle, and extreme outliers are marked with a star. RLU breakpoints are marked with colored lines (RLU 1000 and 3000).

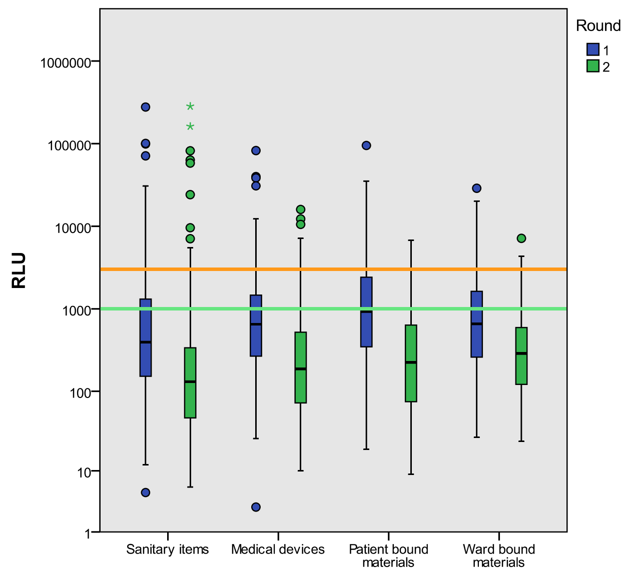

Figure 3 Boxplot of RLU values between fomite groups for each round of measurement. Outliers are marked with a circle, and extreme outliers are marked with a star. RLU breakpoints are marked with colored lines (RLU 1000 and 3000).

Predictors for the more frequent occurrence of 'not clean' (RLU > 1000) surfaces between the first and second round of measurements for the different groups are visualized in Table 1, significant differences are highlighted.

Table 1 Univariable and multivariable analyses of median differences and percentages of 'not clean' (RLU > 1000) items per round, with ARRs. Significant differences in bold ($P < 0.05$). Adjusted models are corrected for hospital, medical specialty and surface category

			Univariable					Multivariable
	>1000 RLU Round 1 (%)	>1000 RLU Round 2 (%)	*P*	ARR (95% CI)	RLU Round 1 (median, IQR)	RLU Round 2 (median, IQR)	ΔRLU	*P*
Hospital								
Hospital 1	15.8	9.1	0.143	0.57 (0.26–1.19)	279 (144–593)	178 (105–525)	101	0.097
Hospital 2	35.8	5.0	<0.001	0.26 (0.10–0.60)	295 (122–747)	83 (35–228)	212	<0.001
Hospital 3	30.0	6.7	<0.001	0.23 (0.10–0.46)	455 (184–1063)	178 (69–351)	277	<0.001
Hospital 4	19.2	10.3	<0.001	0.29 (0.15–0.52)	525 (275–1299)	206 (72–517)	319	<0.001
Hospital 5	47.5	21.5	<0.001	0.45 (0.28–0.72)	807 (271–2296)	329 (133–862)	478	<0.001
Hospital 6	45.0	11.5	<0.001	0.29 (0.11–0.63)	836 (383–1661)	150 (73–438)	686	<0.001
Hospital 7	52.5	23.1	<0.001	0.51 (0.32–0.80)	872 (321–2098)	269 (75–805)	603	<0.001
Hospital 8	40.0	2.5	<0.001	0.05 (0.01–0.13)	1131 (277–1991)	100 (46–216)	1031	<0.001
Hospital 9	71.7	41.7	0.030	0.58 (0.35–0.94)	2137 (895–4798)	830 (239–2621)	1307	<0.001
Medical specialty								
Surgical	40.7	13.4	<0.001	0.33 (0.24–0.44)	627 (241–1592)	200 (72–553)	427	<0.001
Non-surgical	35.1	12.8	<0.001	0.37 (0.27–0.48)	546 (217–1534)	172 (69–474)	374	<0.001
Surface category								
Sanitary items	29.4	11.6	<0.001	0.39 (0.26–0.56)	396 (152–1324)	131 (47–339)	265	<0.001
Patient-bound materials	47.5	15.0	<0.001	0.31 (0.19–0.48)	931 (344–2454)	224 (74–641)	707	<0.001
Ward-bound materials	40.6	14.2	<0.001	0.34 (0.21–0.54)	659 (260–1641)	293 (121–597)	366	<0.001
Medical devices	38.4	13.0	<0.001	0.34 (0.23–0.48)	651 (267–1474)	187 (72–525)	464	<0.001
Total	37.7	13.1	<0.001	0.35 (0.28–0.42)	568 (227–1555)	187 (70–514)	381	<0.001

Discussion

Statement of principal findings

ATP measurements can be used as a fast and objective approach to visualize the level of environmental contamination in hospitals. By using ATP measurement in itself as feedback for nursing staff and cleaning staff, surface contamination can be reduced significantly.

Implications for policy, practice and research

The results of the ATP measurements increased interest and motivation for cleaning among the nursing and cleaning staff. We observed repeatedly that nursing staff voluntarily measured different surfaces on the ward to get insight into surface contamination and consequently improved cleaning of these surfaces. Previous research has shown that performing ATP measurements has a beneficial effect on cleaning in hospital wards, by having an effect on multiple factors e.g. motivation of hospital staff for cleaning surfaces, giving insight into contamination of different surfaces/groups of fomites and giving a quantifiable outcome of measurement [6, 7].

Feedback of ATP measurements to nursing and cleaning staff seems to be an effective method to improve cleaning of hospital wards. Moreover, previous research has shown that cleaning can be improved by implementing relatively simple changes in the cleaning protocol [1]. Within this study each hospital was free to implement cleaning interventions. These interventions included defining cleaning responsibilities per fomite, educational sessions for cleaning staff and/or introduction of new cleaning-wipes. In most hospitals, no cleaning interventions were implemented after feedback of ATP measurements; two hospitals implemented new minor cleaning interventions.

Interpretation within the context of the wider literature

For this study RLU thresholds were copied from a previous study [10]. Different studies have recommended an RLU threshold for cleanliness at 250–500 RLU; however, this threshold is intended for measurement (almost) directly after cleaning [1, 3, 11–14]. Within this study RLU thresholds for conducting ATP measurements at a random point in time were used. The goal of this study was to improve cleaning based on feedback from ATP measurements. By using the above-described thresholds feedback could be given in an easy to visualize way.

Strengths and limitations

During this study, important improvements in hospital cleanliness were observed. Considering the size of the improvement and that it was observed in all centers, it is plausible that these improvements can be contributed to feedback from the ATP measurements. However, it is unknown how long this effect will be maintained. To obtain a sustainable effect, repeated measurements over time will probably be needed. Indeed, other studies have found a washout effect after ATP measurement was ceased [7]. In general, a quality program is characterized by repeated measurements and subsequent actions to improve the result. As such, ATP measurements should be integrated in a quality system for environmental cleaning.

Within three hospitals there was an outbreak with vancomycin-resistant enterococci (VRE) between the first and second round of ATP measurements. Consequently, there was a better focus on cleaning on the affected hospital wards. A part of the decrease in RLU values could be explained by the cleaning measures implemented during these VRE outbreaks. However, a significant decrease in environmental contamination was found in almost all hospitals, indicating that feedback from ATP measurement in itself has a beneficial effect on hospital cleanliness.

Lastly, the additional costs of performing ATP measurements (e.g. purchase costs of luminometers and swabs) can be a limiting factor for using ATP measurement in developing countries.

Conclusions

Substantial differences in RLU values were found after feedback of ATP measurements. The second round of measurements showed significantly lower median RLU values in all groups (hospitals, surface categories and medical specialties), together with significantly lower percentages for 'not clean' surfaces (RLU > 1000) in all groups. These findings suggest that feedback of ATP measurements, presented in a way that is easy to understand, has a beneficial effect on cleaning in general. Furthermore, ATP measurements give insight into specific areas with a high level of environmental contamination to guide specific interventions.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval and consent to participate

Not applicable.

Availability of data and materials

As agreed within the i-4-1-Health consortium, the i-4-1-Health datasets will be made available no earlier than 31 December 2020 and no later than 31 December 2024, in accordance with the FAIR (Findable, Accessible, Interoperable and Reusable) data principles [15].

Authors' contributions

A.V.A. was responsible for data analysis and writing of the manuscript. The manuscript was judged by I.W., P.D.W, I.L.-R., M.V. and J.K. S.V.-W., A.V.O., P.D.W., M.V., E.M., A.V.O., P.W., E.V.A., E.K.-B., K.F. and E.V.C. were responsible for collection of the data. V.S. was responsible for the data analysis. All authors read and approved the final manuscript.

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