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The daily direct costs of isolating patients identified with highly resistant micro-organisms in a non-outbreak setting

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SUMMARY

Background: Isolation precautions are recommended when caring for patients identified with highly resistant micro-organisms (HRMOs). However, the direct costs of patients in isolation are largely unknown.

Aim: To obtain detailed information on the daily direct costs associated with isolating patients identified with HRMOs.

Methods: This study was performed from November until December 2017 on a 12-bed surgical ward. This ward contained solely isolation rooms with anterooms. The daily direct costs of isolation were based on three cost items: (1) additional personal protective equipment (PPE), measured by counting the consumption of empty packaging materials; (2) cleaning and disinfection of the isolation room, based on the costs of an outsourced cleaning company; and (3) additional workload for healthcare workers, based on literature and multiplied by the average gross hourly salary of nurses. A distinction was made between the costs for strict isolation, contact-plus isolation, and contact isolation.

Findings: During the study period, 26 patients were nursed in isolation because of HRMO carriage. Time for donning and doffing of PPE was 31 min per day. The average daily direct costs of isolation were the least expensive for contact isolation (gown, gloves), €28/$31, and the most expensive for strict isolation (surgical mask, gloves, gown, cap), €41/$47.

Conclusion: Using a novel, easy method to estimate consumption of PPE, we conclude that the daily direct costs of isolating a patient differ per type of isolation. Insight into the direct costs of isolation is of utmost importance when developing or updating infection prevention policies.

Introduction

Patients admitted to a hospital can be placed in protective or source isolation during their admission. Protective isolation is used to protect immunocompromised (e.g., prolonged neutropenia) patients from getting a fungal or viral

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infection which is transmitted by air [1]. In this study, we focus on source isolation, which is used to prevent transmission of highly resistant micro-organisms (HRMOs) from carriers to other patients [1,2]. The HRMO involved determines the type of source isolation, including the recommended additional infection prevention and control (IPC) precautions (e.g., personal protective equipment (PPE)) [3–5]. In general, a distinction is made between universal IPC precautions that need to be applied to all patients, regardless of the presence or absence of HRMOs, and transmission-based precautions (IPC precautions on top of universal precautions), which differ per HRMO and thus per type of source isolation.

The World Health Organization (WHO) and Centres for Disease Control and prevention (CDC) formulated guidelines with recommendations on transmission-based precautions, including the selection and use of PPE in healthcare settings [1,6]. Local guidelines are usually derived from these international guidelines, but are often adapted to the local situations (e.g., design of the hospital, availability and costs), and based on findings in literature or on expert opinion [7]. In the Netherlands, the Inspectorate of the Ministry of Health, Welfare and Sport (VWS) audits the implementation of the guidelines from the Working Party on Infection Prevention (WIP) in hospitals [7].

Isolation costs are an addition to the basic cost of care, and would not have been made if the patient was not cared for in isolation. The direct costs of isolation can roughly be divided into the following three items: (1) the costs of using additional PPE; (2) the costs of cleaning and disinfection of an isolation room, during admission and after discharge, and (3) additional personnel costs, because healthcare workers (HCWs) need time for donning and doffing of PPE [4,8]. In this study, indirect costs, which are often costs due to loss of productivity of the hospital, such as a stop on new admissions on a room or ward, or using a multiple-occupancy room for isolation of only one patient, are not included [6,9,10].

The aim of this study was to obtain detailed information on the daily direct costs generated by isolating patients with HRMOs for different types of isolation. Furthermore, to facilitate extrapolation of our results to local situations and policies, we also provide an overview of recommended use of PPE per type of isolation as described by the most common international guidelines.

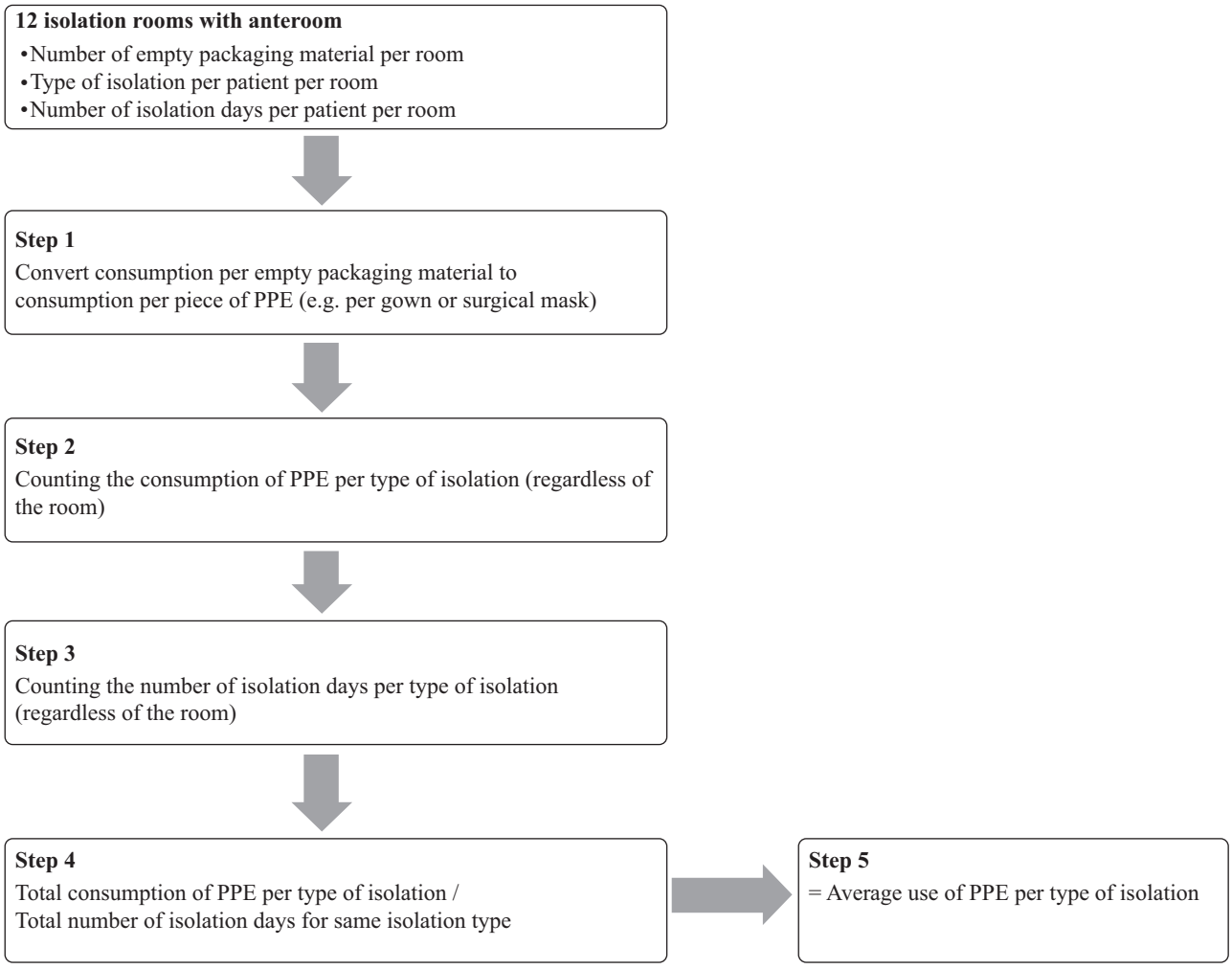

Figure 1. Flowchart of the average use of personal protective equipment (PPE) per type of isolation per day.

Methods

Study design and setting

This observational study was performed during a non-outbreak period from November until December 2017, and conducted at a 12-bed surgical ward at the Erasmus MC University Medical Centre (Erasmus MC), Rotterdam, the Netherlands. This ward contained solely isolation rooms with anterooms. All patients received an isolation label in their electronic patient record, stating the required type of isolation and the isolation indication.

Types of isolation

Patients could be placed into contact isolation (when identifying Enterobacterales, *Stenotrophomonas maltophilia*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae*, or *Enterococcus faecium*, with specific resistance profiles), contact-plus isolation (when identifying carbapenemase-producing Enterobacterales) or strict isolation (when identifying meticillin-resistant *Staphylococcus aureus* (MRSA) or resistant *Acinetobacter* spp.). The indications for the different types of isolation were according to the Dutch WIP guideline for HRMOs [7]. Contact-plus isolation was initiated and implemented by the Erasmus MC for patients identified with carbapenemase-producing HRMOs and is now being used by more Dutch hospitals. We compared the Erasmus MC policy with common IPC guidelines.

Data collection

In all 12 anterooms, we placed a waste bin for the disposal of PPE packaging materials. We informed all HCWs on the ward in multiple ways about the study. Additionally, on the lid of the waste bin we attached an instruction paper with pictures of the packaging materials that had to be thrown in (Supplementary material). We collected the following packaging materials: (1) empty glove boxes, (2) empty packages of disposable gowns, (3) empty packages of surgical masks, (4) empty packages of FFP2-masks, and (5) empty packages of disposable hair caps. Furthermore, at the start of the study, all open packages in the anterooms were replaced by new boxes.

During the study period every workday at around 15.00 h the contents of all 12 waste bins were collected, the amount of packaging materials was counted, and the type of isolation per patient was noted.

Data analyses

We calculated the number of isolation days per patient, using admission and discharge dates of patients admitted to the isolation rooms. Patients without isolation, with protected isolation, or with non-HRMO indication (e.g., viral infections or other contagious diseases) were excluded from the analyses.

The numbers of used packaging material were multiplied by the number of PPE per unit of packaging material (Figure 1, step one). For glove boxes it was multiplied by 100, for disposable gowns by 10, for surgical masks by 50 and for disposable hair caps by 150. The consumption of PPE per type of isolation, and the number of isolation days per type of isolation, were counted (Figure 1, steps two and three). The total consumption of PPE per type of isolation was divided by the total number of isolation days for the same type of isolation (Figure 1, step four), resulting in the average use of PPE per type of isolation per day (Figure 1, step five).

Calculation of cost items

To calculate the average daily direct costs of isolating a patient per type of isolation, we included the following costs items: (1) additional PPE, (2) cleaning and disinfection of the isolation room, and (3) additional workload for HCWs. Throughout the manuscript, we used the exchange rate of €1 = $1.1387 (as at 16th August 2018). All mentioned prices are without 21% VAT. Costs of additional PPE were calculated by multiplying the average use per day of PPE, per type of isolation, by the manufacturers' catalogue prices.

To calculate the costs of cleaning and disinfection we used the amounts the Erasmus MC pays to an outsourced cleaning company. We took the average cleaning costs of 35 weekdays and 12 weekend days, where we made a distinction between types of isolation but also between daily cleaning and cleanings after discharge of the patient.

Time of additional workload for HCWs was based on the study by Roth *et al.* [4]. They calculated that the extra time a nurse needs for donning and doffing of PPE, for a patient in contact isolation while using gowns, gloves and when applicable surgical masks, was approximately 31 min per day. The average gross monthly salary of a nurse, according to the collective agreement of the University Medical Centres 2015–2017 in the Netherlands, is €2632/$2997, resulting in an average gross hourly wage of €17/$19 [11]. This means €9/$10 per day of additional personnel costs for nurses who are caring for patients in isolation. We used the average 'extra workload' of certified nurses, nursing assistants and trainee nurses combined.

Ethics

The Medical Ethics Committee of the Erasmus MC agreed to the ethical requirements of this study, and decided that the study did not require approval according to the Dutch law on Medical Research in Humans (MEC-2015-306).

Results

Guidelines

The recommendations, of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID), WHO and CDC, on the use of PPE for contact isolation are almost the same (Table I). Only the ESCMID guideline does not recommend wearing a gown in contact isolation. The guidelines differ in their recommendations on using surgical masks and hair caps in strict isolation. The ESCMID guidelines do not provide clear recommendations on the use of PPE in strict isolation.

Patient characteristics

During the 47 days of observation, a total of 44 unique patients were hospitalized on the observed ward. Of these 44

Table I
Overview of national and international guidelines regarding infection prevention and control (IPC) measures

IPC measure	Guideline	Isolation type		
		Contact isolation	Contact-plus isolation	Strict isolation
Non-sterile gloves	Erasmus MC	+ HCWs	+ HCWs/visitors	+ HCWs/visitors
	WIP	+	N.A.	+
	ESCMID	+	N.A.	N.A.
	WHO	+	N.A.	+
	CDC-HICPAC	+	N.A.	+
Gowns, long sleeves	Erasmus MC	+ HCWs	+ HCWs/visitors	+ HCWs/visitors
	WIP	-	N.A.	+
	ESCMID	+	N.A.	N.A.
	WHO	+	N.A.	+
	CDC-HICPAC	+	N.A.	+
Surgical mask*	Erasmus MC	-	-	+ HCWs/visitors
	WIP	-	N.A.	+
	ESCMID	-	N.A.	N.A.
	WHO	-	N.A.	-
	CDC-HICPAC	-	N.A.	+
Hair cap	Erasmus MC	-	-	+ HCWs/visitors
	WIP	-	N.A.	+
	ESCMID	-	N.A.	N.A.
	WHO	-	N.A.	-
	CDC-HICPAC	-	N.A.	-
Daily cleaning	Erasmus MC	Cleaning with damp microfibre cloth	Cleaning with damp microfibre cloth	Cleaning with damp microfibre cloth
	WIP	Cleaning dry or wet	N.A.	Cleaning dry or wet
	ESCMID	Cleaning with detergent or disinfectants	N.A.	Cleaning with detergent or disinfectants
	WHO	Cleaning with detergent or disinfectants	N.A.	Cleaning with detergent or disinfectants
	CDC-HICPAC	N.D.	N.A.	N.D.
Cleaning and disinfection after discharge	Erasmus MC	Cleaning with damp microfibre cloth, followed by disinfection with 250 ppm chlorine	Cleaning with damp microfibre cloth, followed by disinfection with 250 ppm chlorine	Cleaning with damp microfibre cloth, followed by disinfection with 250 ppm chlorine
	WIP	N.D.	N.A.	Disinfection of patient room, sanitary room and anteroom with ethanol 70% or chlorine
	ESCMID	Cleaning with detergent or disinfectants	N.A.	Cleaning with detergent or disinfectants
	WHO	Cleaning with detergent or disinfectants	N.A.	Cleaning with detergent or disinfectants
	CDC-HICPAC	N.D.	N.A.	N.D.

CDC-HICPAC, Centres for Disease Control and prevention – Healthcare Infection Control Practices Advisory Committee [26]; Erasmus MC, Erasmus MC University Medical Centre Rotterdam; ESCMID, European Society of Clinical Microbiology and Infectious Diseases [2]; HCW, healthcare worker; HCWs/visitors, IPC measures apply to both HCWs and visitors; IPC, infection prevention and control; N.A, not applicable; N.D. no data; WHO, World Health Organization [24,25]; WIP, Working Party on Infection Prevention [21–23].
+/green = recommended in guideline; -/red = not recommended in guideline.
*Type IIR or FFP1 surgical mask.

patients, 26 (59.1%) were placed in isolation because they were identified with, or suspected of carrying an HRMO. The 26 patients were admitted for a total of 304 isolation days, with a median stay of seven isolation days (range 1–44) (Table II). The most frequently identified HRMOs were MRSA ($N = 5$, 19.2%) and carbapenem-resistant *P. aeruginosa* ($N = 4$, 15.4%) (Table III).

Additional PPE

Table IV gives an overview of the average daily consumption and costs of additional PPE. The mean (median; interquartile range) consumption of PPE for gloves was 33 (34; 34), gowns 8 (8; 5), surgical masks 6 (0; 14), and hair caps 3 (0; 0). The consumption of PPE for strict isolation per day was the most expensive (€17/$20) while the consumption of PPE for contact isolation was the least expensive (€9/$10).

Cleaning and disinfection of the isolation room

Cleaning and disinfection of the isolation room included daily cleaning while the patient was present, and cleaning and disinfection after discharge. The average costs of daily cleaning were €13/$14, ranging from €10/$11 for contact isolation to €15/$17 for strict isolation. The costs of room disinfection after discharge were €18/$20 for contact isolation, €20/$23 for contact-plus, and €25/$29 for strict isolation. The costs per type of isolation were based on the costs of cleaning products and on personnel costs, which equate to €26/$29 per hour.

Costs of isolation per patient

The average daily direct cost per patient were for contact isolation €28/$31, for contact-plus isolation €36/$41 and for strict isolation €41/$47 (Table V).

The additional direct costs per patient, for the entire isolation period, were for contact isolation €111/$126 (median of four isolation days), contact-plus isolation €504/$573 (median of 14 isolation days) and strict isolation €248/$283 (median of six isolation days).

Discussion

In this observational study on a surgical ward, with solely isolation rooms with anterooms, in a tertiary-care centre, we have shown that strict isolation is the most expensive (€41/$47 per patient/day), while contact isolation is the least expensive (€28/$31 per patient/day). This difference in costs can mainly be explained by the difference in consumption of PPE and only partly by the differences in cleaning. The overview with the most common IPC guidelines shows that guidelines sometimes lack recommendations or recommendations differ per guideline, which has an impact on the costs of isolation. In this study, the costs were calculated in detail for the Erasmus MC, which enables other healthcare organizations to alter the data and calculate costs for their own organization.

The method we used to estimate the consumption of PPE, was novel and less complex and labour-intensive than already published methods [4,8,12]. When comparing the costs of PPE for patients identified with MRSA, the costs of PPE in our study (€17/$20) were slightly higher than the costs mentioned by Spence *et al.*($14) [12]. In the Netherlands, patients identified with MRSA are nursed in strict isolation, while in the study of Spence *et al.*, these patients were placed in contact isolation. Using surgical masks and hair caps in strict isolation, besides using gloves and gowns, partly explains the difference in cost. However, the different methods of measuring PPE consumption could have played a role as well. Souverein *et al.* showed costs (e.g., €18) and consumption (e.g., 35 masks/gloves and 15 gowns per day) of PPE for strict isolation, which are more in line with our study [13]. In the study of Verlee *et al.* the daily costs of contact isolation ($35) are higher than in our study (€28/$31) [8]. Verlee *et al.* did not include the costs of cleaning and disinfection of the isolation room, but they did report 43 min of

Table II
Characteristics of the study population

Characteristics	Isolation type		
	Contact isolation	Contact-plus isolation	Strict isolation
No. of patients	13	2	11
Total no. of isolation days	160	28	116
Average no. of isolation days (median; IQR)	12 (4; 20)	14 (14; 3)	11 (6; 8)
Minimum no. of isolation days	1	11	1
Maximum no. of isolation days	44	17	44

HCW, healthcare worker; IQR, interquartile range.

Table III
Identified highly resistant micro-organisms (HRMOs) per type of isolation

Identified HRMOs*	Isolation type		
	Contact isolation	Contact-plus isolation	Strict isolation
Acinetobacter spp.	–	–	1
Carbapenemase-producing *Klebsiella aerogenes*	–	1	–
Carbapenem-resistant *Pseudomonas aeruginosa*	4	–	–
ESBL-producing *Enterobacter* spp.	1	–	–
ESBL-producing *Escherichia coli*	3	–	–
ESBL-producing *Klebsiella pneumoniae*	2	–	–
Escherichia coli	1	–	–
Klebsiella pneumoniae	1	–	–
MRSA	–	–	5
Stenotrophomonas maltophilia	1	–	–
Suspected MRSA	–	–	5
Vancomycin-resistant *Enterococcus faecium*	–	1	–

ESBL, extended-spectrum beta lactamase; HRMO, highly resistant micro-organism; MRSA, meticillin-resistant *Staphylococcus aureus*; WIP,Working Party on Infection Prevention.
* Identification is according to the Dutch WIP guideline for HRMOs [7].

Table IV
Average daily consumption and costs of additional personal protective equipment (PPE)

	Isolation type		
	Contact isolation	Contact-plus isolation	Strict isolation
	Average (median; IQR)	Average (median; IQR)	Average (median; IQR)
Non-sterile gloves			
Consumption	32 (33; 34)	36 (35; 30)	31 (33; 31)
Costs	€4/$5	€5/$6	€4/$5
Gowns			
Consumption	7 (6; 5)	13 (11; 2)	10 (9; 5)
Costs	€4/$5	€8/$9	€6/$7
Surgical masks			
Consumption	0 (0)	5 (7; 13)	17 (15; 20)
Costs	€-/$-	€2/$2	€5/$6
Hair caps			
Consumption	0 (0)	0 (0)	14 (0; 13)
Costs	€-/$-	€-/$-	€2/$2
Total			
Costs	€9/$10	€15/$17	€17/$20

Average use of PPE per type of isolation, according to the guideline of the Erasmus MC University Medical Centre (accessed 6th June 2018). If a package was not completely used, the minimum number was set to 0. In this case PPE was used, but not enough to empty the package and be counted with that patient. Exchange rate on 16th August 2019: € 1 = $ 1.1387. IQR, interquartile range.

daily excess staff time, which might explain the difference in costs of contact isolation. These studies emphasize that it is of utmost importance that authors clearly state which PPE are used per type of isolation and which cost items are included, because this has a great influence on the costs of isolation.

Strengths and limitations

A major strength of this study is that we used an easy to apply, quick method to estimate consumption of PPE by counting empty packaging material. This is in contrast to, for example, the method used by Roth *et al.* where they observed 10 patients for 24 consecutive hours [4]. We believe that counting the used empty packaging material of PPE per room, instead of extracting this from hospital accounting systems or estimating it by IPC staff, as done by Murthy *et al.* and Spence *et al.*, gives valuable and more detailed information [12,14]. Another strength of this study is that daily direct costs were analysed per type of isolation. This provides insights that can be used for IPC policy decision making. A third strength of this study is that the costs per type of isolation were calculated in detail and step by step. This will facilitate translation of our findings to other settings, even though the data were based on Dutch IPC guidelines and on a limited number of patients and isolation days. Unlike our study, most studies focus solely on the costs of contact isolation or on the total costs of an outbreak, instead of defining the costs for all types of isolation [9,10,12,15].

A limitation of this study is that empty packaging material was counted instead of actual used PPE. If a package was not completely used during a patient admission period, the minimum number of used PPE was 0. Even though PPE had been used during this patient period, the empty package was counted with the next patient. However, as we report on group level (i.e. type of isolation), underestimation of actual used PPE is probably small. A second limitation is that we did not measure the time for donning and doffing ourselves. Instead we used the average time for donning and doffing reported by Roth *et al.* [4]. Moreover, when calculating the additional time for donning and doffing, we did not take into account the different types of isolation nor the different HCWs (e.g., physicians, residents, nurses) or visitors that enter the room daily. Verlee *et al.* also calculated the time for donning and doffing, for contact isolation using gloves and gown, of healthcare personnel [8]. They reported 43 min of daily excess time when entering an isolation room in comparison to the 31 min used by Roth *et al.* [4]. A third limitation of our study is that we did not include the indirect costs of isolation. Birgand *et al.*, Montecalvo *et al.* and Otter *et al.* did include indirect costs caused by ward or bed closure, decolonization of patients, increased length of stay and admission stop on a ward [9,10,16]. Birgand *et al.* found that 69% of the overall mean cost, during an HRMO outbreak, was related to loss of hospital income due to a decrease in hospital activity [9]. Moreover, Otter *et al.* reported €822,000 of 'opportunity costs' (i.e. staff time, bed closure and elective surgical missed revenue) in comparison with

Table V
Average daily direct costs of isolation, per isolation day and type of isolation

	Contact isolation		Contact-plus isolation		Strict isolation	
	€	$	€	$	€	$
Cost item 1: additional PPE	9	10	15	17	17	20
Cost item 2: cleaning and disinfection[a]	10	11	13	14	15	17
Cost item 3: additional workload for HCWs[b]	9	10	9	10	9	10
Total costs (95% CI)	28 (27.7–28.3)	31 (30.7–31.3)	36 (35.0–37.0)	41 (40.0–42.0)	41 (39.6–42.4)	47 (45.5–48.5)

Average use of PPE per type of isolation, according to the guideline of the Erasmus MC University Medical Centre (accessed at 6th June 2018). Exchange rate on 16th August 2019: € 1 = $ 1.1387. CI, confidence interval; HCW, healthcare worker; PPE, personal protective equipment.

[a] Final cleaning/disinfection of the isolation room after discharge of the patient is not included. The average cleaning costs are based on 35 weekdays and 12 weekend days.

[b] We used 31 min for donning and doffing, based on the study by Roth *et al.* [4].

€312,000 of 'actual expenditure' (i.e. anti-infective costs, enhanced screening, contact precautions, temporary ward-based monitors of hand and environmental practice, and environmental decontamination) [10]. These studies show that early detection and isolation of HRMO-positive patients is cost-effective, even though long-term isolation and preventive screening are also costly. The fourth limitation is that we did not collect any information on which we can estimate the care burden of the patient. The care a patient needs has a direct effect on the consumption of PPE. Our data were not corrected for this, which could have led to an under- or overestimation of the calculated consumption of PPE per type of isolation. Evans *et al.* showed that patients in isolation often have a higher severity of illness than non-isolated patients [17]. However, other papers, including the study of Evans *et al.*, also show that patients in isolation tend to get less and shorter attention of HCWs when compared with non-isolated patients [17—20]. To be able to calculate the costs of isolation even more accurately in the future, it is important to also take into account the care burden of the patient.

In conclusion, the direct costs of isolating a patient for one day differs per type of isolation, with strict isolation (i.e. isolation in single-patient room and using surgical mask, gloves, gown and cap) being the most expensive. Furthermore, in our study, the costs of PPE contributed the most to the differences in costs of isolation. Insight into the direct costs of isolation is of utmost importance when developing or updating IPC policies and to be able to perform cost-effectiveness analyses where costs and effects of IPC measures are studied.

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Conflict of interest statement
The authors state no conflicts of interest.

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Appendix A. Supplementary data

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