REUE | Original Article

Chemical decontamination in the emergency department: epidemiology, clinical features, treatment, and clinical course

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OBJECTIVE. To analyze epidemiologic and clinical characteristics of cases of eye or skin exposure to chemicals, and to evaluate clinical course according to decontamination protocol used.

MATERIAL AND METHODS. Over a period of 7 years we prospectively collected information on cases of exposure to chemical agents in patients treated in the chemical decontamination area of our emergency department. Patients were distributed according to type of exposure. In the first group, individuals had been exposed to caustic products or personal defense sprays, for which washing with a polyvalent solution was indicated for decontamination. In the second, individuals were exposed to detergents, alcohols, solvents, or noncaustic products, for which water or soap and water were indicated.

RESULTS. A total of 156 patients were studied. The median age was 35 years (interquartile range, 21 years), and 50% were men. Caustic agents accounted for the largest proportion of exposures (36.5%), and the eyes were the organ most often affected (64.8%). Workplace accidents caused 45.8% of the events. The group exposed to caustic agents comprised 85 patients. Seventy-one rinsed with a polyvalent solution. Symptom improvement was significantly better after such treatment than after decontamination with water ($P = .016$), but we saw no significant differences in pain measured on a pain scale ($P = .442$), the need for 2 or more follow-up visits ($P > .05$), or the persistence of signs or symptoms after 30 days ($P = .072$). Of the 71 patients exposed to noncaustic agents, 58 were decontaminated with water. When rinsing with water was compared to rinsing with a polyvalent solution in this group, there were no significant differences in subjective evaluation of improvement ($P = .696$), pain relief ($P = .918$), need for 2 or more follow-up visits ($P > .05$), or persistence of signs or symptoms ($P = .352$).

CONCLUSIONS. Decontamination is effective for improving symptoms of exposure. A polyvalent solution gives better results than water after exposure to a caustic agent or a personal defense spray. Other chemical exposures can be treated as well with water.

Keywords: Chemical burn. Chemical decontamination. Emergency department. Triage, advanced. Nursing. Chemical decontamination area.

Evaluación epidemiológica, clínica, terapéutica y evolutiva de las descontaminaciones químicas realizadas en urgencias

OBJETIVO. Analizar las características epidemiológicas, clínicas, terapéuticas y evolutivas de los pacientes atendidos tras una exposición química con afectación ocular y/o cutánea.

MATERIAL Y MÉTODOS. Durante 7 años, se recogieron variables de los pacientes expuestos a algún agente químico y que fueron atendidos en el área de descontaminación química de urgencias. Se hicieron dos grupos, el primero (A) integrado por individuos contaminados con productos cáusticos o espráis de defensa personal y en los que estaba protocolizado el uso como descontaminante de una solución polivalente y el segundo (B) formado por pacientes contaminados con detergentes, alcoholes, disolventes o productos no cáusticos y que sólo se tenían que descontaminar con agua o agua y jabón.

RESULTADOS. Se incluyeron 156 pacientes con una edad mediana de 35 (21) años, siendo hombres el 50%. Los productos más implicados fueron los cáusticos (36,53%) y los ojos el órgano más afectado (64,8%). Hubo un 45,8% de accidentes laborales. En el grupo A hubo 85 pacientes, de los cuales 71 se descontaminaron con la solución polivalente. El empleo de esta se asoció a una mejoría significativa de los síntomas en comparación con el agua ($p = 0,016$). No hubo diferencias significativas en el descenso del dolor medido por la escala ENA ($p = 0,442$), ni en la necesidad de dos o más visitas médicas tras el incidente ($p = 1$) ni en la persistencia de signos o síntomas pasados 30 días ($p = 0,072$). El grupo B incluyó 71 individuos, de los cuales 58 recibieron tratamiento con agua. Al comparar el uso o no de la solución polivalente, no se observaron diferencias significativas en la mejoría subjetiva ($p = 0,696$), ni en la reducción del dolor ($p = 0,918$), ni en la necesidad de dos o más visitas médicas posteriores ($p = 1$) ni en la persistencia de signos o síntomas postexposición ($p = 0,352$).

CONCLUSIONES. La descontaminación es eficaz para mejorar la sintomatología del paciente. En productos cáusticos o espráis de defensa personal se obtienen mejores resultados con la solución polivalente, mientras que con otros agentes químicos el agua obtiene los mismos resultados.

Palabras clave: Quemadura química. Descontaminación química. Urgencias. Triaje avanzado enfermería. Área de descontaminación química.

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Article Information: Received: 14-6-2024. Accepted: 1-7-2024. *Online:* 20-8-2024.
Editor in Charge: Guillermo Burillo-Putze.

Introduction

In an industrialized world, exposure to chemical products affecting the skin and eyes is common. In Spain, this route of exposure accounts for 14% of all chemical product exposures treated in emergency departments (EDs), according to the National Toxicovigilance Program.[1] These exposures pose a risk of local injury in the form of chemical burns, particularly after contact with caustic or corrosive substances, but also carry the risk of absorption and systemic effects—especially with highly liposoluble compounds—which may induce multiorgan manifestations with potential mortality, as seen with pesticides, particularly organophosphorus insecticides.[2]

After cutaneous or ocular contact with a chemical substance, local lesions may result from various chemical reactions, including oxidation, reduction, corrosion, formation of protoplasmic poisons, or induction of vesicant or dehydrating processes. The severity of these lesions depends on the physicochemical properties of the agent, the amount and concentration of the product, the duration of contact, its penetration capacity, and ultimately, the mechanism of action of the agent.[3] At ocular level, these reactions may trigger an immediate inflammatory process (keratoconjunctivitis) characterized by severe pain, tearing, photophobia, and conjunctival hyperemia that, in extreme cases, may result in ocular perforation or sequelae such as loss of visual acuity.[4]

At skin level, similar mechanisms can produce varying degrees of burns with pain and irritation that may progress to deep necrosis, leading to pigmentation changes, contractures, and keloids.[5] To prevent or reduce these risks after exposure to chemical products, the most effective treatment is early and intensive cutaneous and ocular decontamination (COD).[6]

Several methods can be used for efficient COD: washing with water, with water and soap, with saline solution, with amphoteric or polyvalent solutions, or with other specific formulations such as polyethylene glycol. The choice of method depends on the type of chemical agent, the time elapsed since exposure, and the affected area.[7] Decontamination is usually performed by emergency medical services personnel, although many patients present directly to EDs[8] or require hospital-based COD procedures.[9] To optimize these interventions, the ideal patient location is a dedicated chemical decontamination area (CDA) adjacent to the ED,[10] equipped with the necessary materials for patient decontamination and healthcare staff protection, as well as a standardized operating protocol (SOP) that covers the various possible scenarios.

The objective of this study was to analyze the epidemiological, clinical, therapeutic, and outcome characteristics of patients treated in a hospital-based CDA after cutaneous or ocular exposure to chemical agents and to assess quality and safety criteria.

Material and methods

We conducted a single-center, observational, and analytical study over 7 years (2010–2016). Epidemiological, toxicological, clinical, and therapeutic variables were prospectively collected from patients aged > 18 years who were splashed with or otherwise exposed to chemical agents and treated in the CDA of the ED of Hospital Clínic de Barcelona (Barcelona, Catalonia, Spain).

Care in the CDA was standardized based primarily on 2 factors: (1) the type of chemical agent and (2) the time elapsed since exposure.[11] All decontamination procedures were described in an internal SOP developed by the hospital's Clinical Toxicology Section and ED nursing staff and approved as an advanced nursing triage document by hospital and emergency leadership. The SOP included the use, under specific conditions, of a polyvalent, hypertonic, amphoteric, and chelating solution (Diphoterine®) as a decontaminant.[12]

Patients were categorized into 2 groups. Group A included those contaminated with corrosive products (acids, bases, oxidants) or attacked with personal defense sprays. In these cases, due to the potential severity of the toxic agent or the intensity of symptoms, the use of the polyvalent solution was protocolized if treatment occurred within 1 hour of exposure. Group B included those contaminated with detergents, alcohols, solvents, and other agents of lower toxicity, or treated later than one hour after exposure. These patients were decontaminated only with water (for ocular exposure) or with water or water and soap (for skin exposure), according to the SOP. Deviations from the protocol—such as alternative decontamination methods due to material shortages, lack of toxicological identification, or miscalculation of exposure time—were reported to assess adherence to quality and safety standards, based on the SOP and the Calitox-2006 Quality Indicators in Toxicology.[13]

Data were extracted from nursing records and medical reports. Pain was assessed using a Numeric Analogue Scale (NAS).[14]

To assess patient outcomes, the shared medical record was reviewed. The need for 2 or more medical consultations related to the incident or the persistence of signs or symptoms 1 month after exposure was evaluated. The treatment administered by the ED physician (ophthalmologist, surgeon, or internist) was also taken into account, after the nurse who performed the decontamination had referred the patient to the appropriate physician. The variables were entered into an SPSS database (version 15.0). Qualitative variables were expressed as absolute numbers and percentages (%), and quantitative variables as mean ± standard deviation (SD) or as median with interquartile range (IQR). For the statistical comparison of qualitative variables, the chi-square test was used, or alternatively Fisher's exact test when expected frequencies were < 5, after grouping categories into a 2×2 table. For quantitative variables, the Student t test was used when data were normally distributed, as verified by the Kolmogorov–Smirnov test; if the assumption of normality was violated, the nonparametric Mann–Whitney U test was used. A P value < .05 was considered statistically significant.

The study was approved by Hospital Clínic of Barcelona Clinical Research and Ethics Committee.

Results

A total of 156 patients were included (median age, 35 [21] years; 50% men). Most CDA consultations occurred during the afternoon (3–10 p.m.). The most frequent agents were caustics (36.5%) and solvents or degreasers (16.2%). Occupational (45.8%) and domestic (34.8%) accidents were the most common causes, with ocular exposure being the leading reason for consultation (64.8%) (Table 1).

The exposure-to-arrival interval was < 1 hour in 75.8% of cases (median, 30 minutes), and patients were treated immediately (mean waiting time, 4.3 minutes). Initial treatment involved water (38%), water and soap (4.5%), or a hypertonic, amphoteric, chelating solution (53.5%). Subjective improvement was reported by 70.1% of patients, with NAS scores dropping from 5.65 down to 3.01 after decontamination ($P < .001$). Median CDA stay was 36 minutes. Ocular sequelae occurred in 3.3% and cutaneous sequelae in 1.2% of patients.

Group A included 85 individuals exposed to caustic/corrosive products or personal defense sprays (Table 2). A total of 71 patients were treated with the amphoteric solution, which was associated with greater subjective improvement vs water (85.9% vs 50%, $P = .016$) and a larger reduction in pain scores (2.5 vs 1.9, $P = .442$). No significant differences were found in the need for ≥ 2 medical visits (16.9% vs 14.3%, $P = 1$) or in the persistence of signs/symptoms after 30 days (1.7% vs 14.3%, $P = .072$).

Group B included 71 patients (Table 3), 58 of whom were treated with water. Compared with the polyvalent solution, no significant differences were observed in subjective improvement (70% vs 76.5%, $P = .696$), pain reduction (2.6 vs 2.2, $P = .918$), need for ≥ 2 medical visits (11.1% vs 19.2%, $P = 1$), or persistence of symptoms after 1 month (11.1% vs 3.8%, $P = .352$).

Six patients who developed sequelae had been contaminated with corrosive products, and 4 of them had been decontaminated with water only. One woman with cutaneous exposure after ingesting sulfuric acid in a suicide attempt died from massive ingestion.

Decontamination was correctly performed using the polyvalent solution according to protocol in 86.1% of patients. No adverse effects associated with the solution were observed, and no healthcare workers were contaminated during the procedures. Legal reporting was required in 52.2% of cases.

Table 1. Patients with exposure to chemical products treated in the chemical decontamination area (n = 156)

Age (years; median and IQR)	35 (21)
Sex (men) [n (%)]	78 (50)
Main toxic agent [n (%)]	Sodium hypochlorite, 24 (15.4)
	Defense sprays, 16 (10.3)
	Alcohols, 15 (9.6)
	Glues and adhesives, 14 (9.0)
	Caustic soda, 11 (7.1)
	Solvents, 10 (6.4)
	Sulfuric acid, 9 (5.8)
	Degreasers, 8 (5.1)
	Hydrochloric acid, 5 (3.2)
	Acetic acid, 3 (1.9)
	Peracetic acid, 3 (1.9)
	Ammonia, 3 (1.9)
	Chlorhexidine, 2 (1.3)
	Phenol, 2 (1.3)
	Others, 34 (21.8)
Intent [n (%)]	Occupational accident, 69 (44.2)
	Domestic accident, 54 (34.6)
	Assault, 24 (15.4)
	Suicide attempt, 1 (0.6)
	Unspecified, 7 (4.5)
Affected area [n (%)]	Ocular, 101 (64.7)
	Cutaneous, 23 (14.7)
	Ocular and cutaneous, 32 (20.5)
Time from contamination to self-decontamination [n = 85] (minutes; median and IQR)	1 (4)
Time from contamination to arrival at ED [n = 140] (minutes; median and IQR)	30 (40)
Time from arrival at ED to decontamination [n = 52] (minutes; mean and SD)	4.3 (5)
Subjective improvement after treatment [n = 138] [n (%)]	108 (78.3)
Pain score (NAS) at admission [n = 67] (median and IQR)	6 (5)
Pain score (NAS) at discharge [n = 67] (median and IQR)	3 (4)
Reduction in NAS points before and after decontamination treatment [n = 67] (median and IQR)	3 (4)
Need for 2 or more medical visits after ED discharge [n = 132] [n (%)]	23 (17.4)
Persistent signs or symptoms 30 days after ED discharge [n = 132] [n (%)]	6 (4.5)

IQR: interquartile range; ED: emergency department; NAS: Numeric Analogue Pain Scale.

Discussion

Cutaneous or ocular contamination with chemical products is a relatively frequent occurrence and may involve a wide variety of substances.[15] Individual accidents of limited magnitude are typically seen in hospitals, since large-scale industrial or mass-exposure incidents are usually managed by prehospital emergency services. However, EDs must always be prepared to provide care for such events, including adequate knowledge of decontamination techniques,[16] as accidents are unpredictable, may result in mass casualties, and often require immediate action. Furthermore, as demonstrated by the sarin gas terrorist attack in the Tokyo subway, many patients may present spontaneously to hospitals.[17]

Hospital Clínic has maintained a CDA at the ED entrance since 2009, equipped with the necessary materials for its function, as previously described.[18] Nursing staff have been trained to perform decontamination, and through advanced triage procedures, decontamination can begin immediately. Nurses record patient data and treatment details, and following decontamination, patients are systematically referred to the ophthalmologist, internist, or on-call surgeon for further evaluation and management.

Table 2. Group A: Patients with recent exposure (< 2 hours) to caustic, corrosive, or oxidizing agents, or attacked with personal defense sprays, indicated for treatment with an amphoteric and chelating solution (n = 85)

	Total	Treated with amphoteric and chelating solution (n = 71)	Treated with water (eyes) or water and soap (skin) (n = 14)	*P* value
Age (years)	34 (14)	34 (14)	31 (15)	.974
Sex (men) [n (%)]	50 (58.8%)	38 (53.5%)	12 (85.7%)	.054
Main toxic agent (n)	Sodium hypochlorite (17)	16	1	.413
	Defense sprays (16)	10	6	.010
	Caustic soda (11)	10	1	.499
	Sulfuric acid (9)	9	0	.142
	Hydrochloric acid (5)	5	0	
	Acetic acid (3)	0	3	
	Peracetic acid (3)	3	0	
	Ammonia (3)	2	1	
	Phenol (2)	2	0	
	Others (19)	14	2	
Intent [n]	Occupational accident (35)	29	6	.940
	Domestic accident (25)	23	2	.125
	Assault (20)	14	6	.339
	Suicide attempt (1)	1	0	
	Unspecified (4)	3	0	
Affected area [n]	Ocular (44)	37	7	.893
	Cutaneous (17)	13	4	.566
	Ocular and cutaneous (24)	21	3	.517
Time from contamination to self-decontamination (minutes)	1 (10)	1 (10)	1 (9.6)	.816
Time from contamination to arrival at ED (minutes)	30 (107)	30 (118)	30 (13.6)	.284
Subjective improvement after treatment (n = 77) [n (%)]	62 (74%)	55 (85.9%)	7 (50%)	.016
Pain score (NAS) at admission (n = 34)	6,5 (2,7)	6.4 (2.6)	7.5 (3.4)	.706
Pain score (NAS) at discharge (n = 34)	3 (2,1)	2.5 (1.8)	3 (3.3)	.171
Reduction in NAS points before and after decontamination treatment (n = 34)	3 (2,4)	3 (2.5)	2.5 (1.9)	.442
Need for 2 or more medical visits after ED discharge (n = 71) [n (%)]	12 (16,9%)	10 (16.9%)	2 (14.3%)	1
Persistent signs or symptoms 30 days after ED discharge (n = 71) [n (%)]	3 (4,2%)	1 (1.7%)	2 (14.3%)	.072

NAS: Numeric Analogue Pain Scale; ED: emergency department.
For variables with total values ≤ 5, statistical significance was not calculated.

Chemical contamination can cause 2 types of signs: local and systemic. Local effects result from the physicochemical properties of the substance (pH, acid or alkaline titration reserve, oxidation capacity), leading to irritation or corrosive burns. Systemic effects are linked to the liposolubility of the product, which facilitates absorption and may cause systemic toxicity, as seen with pesticides, hydrocarbons, and several chemical warfare agents.[19] Systemic effects may also result from chelating actions, such as those caused by the fluoride ion in hydrofluoric acid, which binds calcium and induces severe neurological and cardiovascular complications that can be fatal.[20] After the acute phase, there is always a risk of sequelae, affecting either the skin[21] or the eyes,[22] potentially resulting in blindness. Thus, medical follow-up after decontamination is essential.

The data from this study highlight the epidemiological importance of occupational accidents. Although Hospital Clínic is a general hospital and not an occupational health facility, numerous work-related incidents were treated, underscoring the importance of preventive campaigns to reduce such accidents in the workplace.[23] Domestic accidents were also frequent, confirming that the home can be a hazardous environment from a toxicological standpoint.[8,24] Among intentional exposures, assaults using personal defense sprays stand out. These devices are easily accessible in Spain and are sometimes misused for other purposes, such as robbery or interpersonal violence.[25]

Although the number of chemical burn cases was small vs other conditions or injuries, their management was more frequent than that of other types of burns, albeit typically less extensive. Nonetheless, their evolution and sequelae were comparable to those of thermal burns.[26] The most widely affected organ was the eye, usually due to splashes of corrosive products—particularly alkaline agents—at home, in the workplace, or during assaults. This finding underscores the need for protective measures when handling chemicals, such as wide polycarbonate safety goggles or nitrile gloves resistant to corrosive agents.[27]

Of note, chemical burns often cause intense pain and anxiety, especially when the eyes are affected, prompting patients to seek emergency care rapidly, as observed in this study. Many patients had already attempted self-decontamination with water, albeit insufficiently. Our findings clearly show that abundant and prolonged washing with water alone significantly reduces pain and symptoms, by

Table 3. Group B: patients with delayed exposure (> 2 hours) or exposed to alcohols, glycols, ketones, or other hydrocarbons, without indication for treatment with an amphoteric and chelating solution (n = 71)

	Total	Treated with amphoteric and chelating solution (n = 13)	Treated with water (eyes) or water and soap (skin) (n = 58)	*P* value
Age (years)	35 (14.3)	36 (17.3)	35 (13.7)	.411
Sex (men) [n (%)]	28 (39%)	4 (30.8)	24 (41.4)	.452
Main toxic agent (n)	Alcohols (15)	4	6	.210
	Glues and adhesives (14)	4	10	.391
	Solvents (10)	2	10	.183
	Degreasers (8)	1	7	.573
	Sodium hypochlorite (7)	1	6	.831
	Chlorhexidine (2)	0	2	
	Others (15)	1	14	
Intent [n]	Occupational accident (34)	3	31	.017
	Domestic accident (29)	7	22	.375
	Assault (4)	1	3	
	Other or unspecified (4)	2	2	
Affected area [n]	Ocular (57)	12	45	.556
	Cutaneous (6)	0	6	.759
	Ocular and cutaneous (8)	1	7	.639
Time from contamination to self-decontamination (minutes)	1 (11.43)	1.5 (9.5)	1 (11.9)	.990
Time from contamination to arrival at ED (minutes)	35 (143.5)	32 (31)	35 (154)	.057
Subjective improvement after treatment (n = 61) [n (%)]	46 (75.4%)	7 (70%)	39 (76.5%)	.696
Pain score (NAS) at admission (n = 34)	6 (3.6)	7 (3.7)	5.5 (3.6)	.994
Pain score (NAS) at discharge (n = 34)	3 (2.8)	3 (2.8)	3 (2.8)	.939
Reduction in NAS points before and after decontamination treatment (n = 34)	2 (2.2)	2 (2.6)	2 (2.2)	.918
Need for 2 or more medical visits after ED discharge (n = 61) [n (%)]	11 (18.0%)	1 (11.1%)	10 (19.2%)	1
Persistent signs or symptoms 30 days after ED discharge (n = 61) [n (%)]	3 (4.9%)	1 (11.1%)	2 (3.8%)	.352

NAS: Numeric Analogue Scale; ED: emergency department.
For variables with total values ≤ 5, statistical significance was not calculated.

diluting and removing the chemical product, thereby decreasing burn severity and subsequent sequelae.[28]

Moreover, in recent years, to further improve the prognosis of caustic chemical injuries to the skin and mucosa, a polyvalent solution has been introduced that neutralizes the 6 types of reactions chemical agents may cause. Being hypertonic, chelating, and amphoteric, this solution not only dilutes and removes the chemical but also draws it outward, creating neutral residues without generating exothermic reactions.[29] Few studies have evaluated its clinical effectiveness in hospital settings, as it is difficult to recruit sufficiently homogeneous patient series for comparison with water or other solutions.[30] We therefore considered it relevant to contribute our experience with this European Union–approved medical product for this specific indication.[31] In Group A patients, treatment with the polyvalent solution produced better outcomes than water alone, although statistical significance was reached only for symptom improvement (including pain, itching, burning, blepharospasm, photophobia, etc.). While pain reduction did not reach significance, patients reported immediate relief and relaxation after application of the solution compared with water. Conversely, in Group B, better outcomes were observed with water, though not statistically significant, likely due to the sample size. These findings support the SOP in use at our institution, which reserves the polyvalent solution for patients exposed to corrosive agents or defense sprays and treated within 1 hour of exposure. In all cases, the effectiveness of any decontamination method is closely tied to the timeliness of its application, as delayed intervention may lead to irreversible cutaneous or ocular injury or completed systemic absorption.

However, the results also reveal that SOPs are not always followed, likely due to lack of awareness, new staff, or other factors. Compliance with a minimum standard of 90% in applying the appropriate decontaminant for each case was not achieved, underscoring the need for continuous monitoring and staff education to improve quality of care.[32] Conversely, quality and safety standards were met regarding immediate decontamination (within 20 minutes of arrival) and appropriate safety measures, as no healthcare personnel experienced self-contamination. The number of legal notifications was lower than expected, considering that occupational accidents and assaults should always be reported.

This study has several limitations, including the heterogeneity of the chemical agents involved and variability in lesion severity (extent and depth). Although most cases were not severe, this diversity limited deeper analyses of efficacy. Additionally, follow-up was not possible for some patients referred to occupational health services or private hospitals.

Conclusions

Cutaneous and ocular contamination with chemical products is common and diverse. Decontamination is effective in improving patient symptoms. For corrosive products or personal defense sprays, decontamination with a hypertonic, amphoteric, and chelating solution yields better results, whereas for other chemical agents, water achieves comparable efficacy.

Regular SOP monitoring and staff education are essential to maintain high standards of quality and safety in the management of these patients.

ARTICLE INFORMATION

Conflict of Interest Disclosures: None reported.

Funding: This research was supported by a competitive grant from the Intensification of Nursing Research Activity Program (Intensificació de l'activitat investigadora de personal d'infermeria), within the Strategic Plan for Health Research and Innovation (IPI-PERIS), from the Catalan Department of Health (Grant No. SLT002/16/00314).

Ethical responsibilities: The authors have confirmed the maintenance of confidentiality and respect for the patient rights, agreement of publication, and transfer of rights to Revista Española de Urgencias y Emergencias.

Article not commissioned by the Editorial Board and with external peer review.

Note of the editors: This is a BOWMAN-generated English translation of the officially indexed Spanish-language article, which should be cited as Rev Esp Urg Emerg. 2024;3:214-220. In this translated version, the editors have supervised the process; however, it cannot be ruled out that some errors resulting from the artificial intelligence translation process may have gone unnoticed.

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