Vol. 18(1), pp. 6-20, January 2024
DOI: 10.5897/AJEST2023.3243
Article Number: FC17D6171708
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

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African Journal of Environmental Science and Technology

Full Length Research Paper

An assessment of health care waste generation rates in public, faith-based and private health facilities in Douala, Littoral Region of Cameron

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Received 21 October, 2023; Accepted 18 December, 2023

Healthcare wastes are potentially dangerous to both humans and the environment due to their unique characteristics. The quantity generated continues to increase in varying proportions across different healthcare facilities, partly based on ownership and management styles, which represent significant constraints on healthcare delivery. This study assessed healthcare waste generation rates and management systems in eleven healthcare facilities (representing three types of hospitals) in Douala, the Littoral Region of Cameroon. Data were collected through a quantitative survey, using questionnaires and were subjected to descriptive and inferential statistics. Comparatively, more waste was generated in Public Hospitals (2257.52 kg) than in Private Hospitals (831.2 kg) and Faith-Based Hospitals (789 kg). The median quantity of waste generated/bed/day by Private Hospitals was greater than that generated by Faith-Based and Public Hospitals, with values of 0.22 > 0.19 > 0.09 kg/bed/day, respectively. Similarly, the median quantities of waste generated/patient/day stood at 0.31 > 0.11 > 0.09 kg/patient/day for private, faith-based, and public hospitals, respectively. The linear regression model used for predicting waste generation rates by outpatients yielded R2 values in order of 0.9732, 0.9298, and 0.7275 for Private, Public, and Faith-Based Hospitals, respectively. This indicates that the number of outpatients accounts for 97, 92, and 72% of the total variance explained in solid waste generation in the hospitals. The quantity of hazardous waste ranged from 43.63 to 81.4%. In conclusion, the total hazardous waste generated is higher than the nonhazardous waste in the healthcare facilities.

Key words: Douala Cameroon, Healthcare facilities, healthcare waste, waste generation, waste composition, general waste, hazardous waste.

INTRODUCTION

The provision of healthcare, aimed at restoring and improving health, is also responsible for generating vast quantities of waste. These wastes consist of approximately 25% non-hazardous and 75% hazardous components, respectively (WHO, 2011; Ezeudu et al., 2022). Medical waste classified as non-risk or general healthcare waste is comparable to domestic waste and mainly originates from the administrative and housekeeping functions of healthcare establishments, including waste generated during the maintenance of healthcare premises. On the

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other hand, hazardous waste, consisting of infectious, pathological, chemical, sharps, and radioactive materials, has the potential to pose various health risks (WHO, 2011).

Of the two types of hospital waste, more attention is typically given to hazardous waste due to its severe impact. According to a WHO report, approximately 85% of hospital wastes are nonhazardous, while the remaining 10-25% is considered hazardous. A study conducted at the Mizan Tepi University Teaching Hospital (MTUTH) in the Bench Maji Zone, South West Ethiopia, revealed different types of wastes in the waste stream, including pathological waste (0.033 kg/bed/day), infectious waste (0.02 kg/bed/day), general waste constituting 32.3%, pharmaceutical waste (0.011 kg/bed/day, 6.7%), and sharps (0.009 kg/bed, 5.5%). This result contrasts with a World Health Organization (WHO) report, which suggests that the distribution of healthcare wastes from hospitals in developing countries is expected to be 15% pathological and infectious waste, 1% sharp waste, and 3% pharmaceutical waste.

Improper handling of hazardous components poses health risks to both humans and the environment, with the magnitude of these risks increasing as waste output rises. The amount of healthcare waste has seen an upward trajectory due to increased access to healthcare- a global development priority outlined in Sustainable Development Goal 3, which aspires to end epidemics and communicable diseases. Furthermore, improved medical diagnosis, mass immunization campaigns, and the changing pattern of diseases, such as the COVID pandemic, have contributed to increased investment in the health sector and a spike in waste generation.

The capacity of any health facility to provide high-quality healthcare is closely linked to its healthcare waste management standards (Sanida et al., 2010). According to WHO reports, the quantity of healthcare waste (HCW) produced by any medical institution depends on its size and varies from one country to another, correlating with national income and the level of development (Marinkovic et al., 2008). Previous studies have noted variations in the quantities of healthcare waste generated between developing regions and developed nations, as well as from country to country.

Marinkovic et al. (2008) observed that highly developed countries produce higher quantities of medical waste than middle and less developed countries. Diaz et al. (2008) suggested that medical waste generation in developed nations ranges from 1.2 to 200 times more than that generated in developing countries. In terms of quantities generated, WHO (2011) reported that East Asia, Eastern Europe, and the Middle East produce 1.3 kg/bed/day. Healthcare waste generation rates are given as 0.54, 0.34, 2.0, and 1.4 for Taiwan, the Philippines, Portugal, and Greece, respectively (Cheng et al., 2009; Diaz et al., 2008; Tsakona et al., 2007). Rates of hazardous components have been reported as follows: 0.25 kg/bed/day (Bangladesh), 0.4 to 1.9 kg/bed/day (Iran), and 1.4 kg/bed/day (Greece) (Patwary et al., 2009; 2011; Taghipour and Mosaferi, 2009).

The quantity of waste generated also varies depending on the department. For instance, in the Mizan Tepi University Teaching Hospital (MTUTH), Bench Maji Zone, South West Ethiopia, the gynecological ward contributed the largest portion of total waste, accounting for 5.08 kg/day (28.90%), while the office generated the lowest proportion at 0.22 kg/day (1.30%).

The issue of healthcare waste is particularly challenging in developing countries. WHO (2004) reported that, from an assessment of 22 developing countries, 18% to 64% of healthcare facilities do not use proper waste disposal methods. In Sudan, Ahmed et al., (2014) noted that healthcare waste management practices observed in Khartoum state hospitals were not fully safe and had harmful environmental effects, characterized by the absence of continuous segregation, collection, transportation, and final disposal methods for pathological and other medical wastes. Similar reports have been documented in Ethiopia (Tesfahun and Kume, 2007).

Therefore, the poor management of healthcare waste in hospitals remains a significant problem in most countries. Factors such as hospital policies and practices, staff strength, number of patients, and the type of care provided influence the quantity of healthcare waste generated. In developing countries, a range of 1-5 kg/bed/day of waste is generated, with substantial intra and inter-country specialty differences. It is reported that in rural hospitals in Africa, the total generation rate of medical waste is estimated to be between 0.3-1.5 kg/bed/day (5-20% hazardous waste) (Yadav, 2001).

Improving existing waste management practices is imperative to prevent exposure of various community groups. The availability of adequate data on waste generation and management practices in healthcare facilities plays a crucial role in planning appropriate methods. The city of Douala in Cameroon is home to various categories of healthcare facilities, including privately owned, Faith-Based, and government/public facilities. There has been a public outcry regarding the nature of services provided by these health facilities.

A survey on the level of user satisfaction with health services delivered in Douala revealed that, apart from the convenience of location for user access, which was rated moderately satisfactory, satisfaction levels for other components such as the skill and competency of medical staff, speed in completing examinations and reports, equipment for modern diagnosis and treatment, accuracy and completeness in filling out reports, friendliness and courtesy of the staff, responsiveness (waiting time) in medical institutions, and satisfaction with cost were generally rated low. These components also have a multiplier effect on the quantity of waste generated.

However, there is a paucity of data related to the

aforementioned issues at the individual hospital level. Therefore, the objective of this study was to determine the average generation of healthcare waste (HCW) per different hospital categories in Douala, analyze possible statistical differentiations among those categories, and compare calculated generation rates with other available references. This study aims to facilitate benchmarking of the facilities, allowing for comparisons of generation rates to identify possibilities for improving the efficiency of their waste management systems.

METHODS AND MATERIALS

Study area and period

The present study was conducted in three types of hospitals (Public, Private, and Faith-Based) in Douala, located in the Littoral Region of Cameroon. Douala is one of the most industrialized cities in the country, situated at latitude 4o 2' 53" and longitude 9° 42' 15" E, on the southeastern shore of the Wouri Coast, approximately 130 miles (210 km) west of Yaoundé. The Littoral Region is bordered by the West Region to the North, the Centre Region to the East, the South Region and the Gulf of Guinea to the South, and the South West Region to the West. The city has a projected population of 5,768,400 in 2021, compared to the 1,906,962 recorded in 2005. The area experiences a humid equatorial climate, with a mean annual temperature of 26°C, mean monthly temperatures consistently above 25°C, and daily temperatures often exceeding 31°C.

The healthcare delivery system in Cameroon is characterized by multiple providers, including the public sector, private sector, religious establishments, and private enterprises. In 1999, there were 1,689 health centers and 339 hospitals, with 67% operated by the Ministry of Public Health (MINSANTE) and the remaining managed by the private sector. Both sectors play complementary roles to improve the quality and accessibility of healthcare. Douala has ten health districts, displaying significant geographic inequalities, with some districts having a higher number of physicians per person than others, leading to poor health outcomes. About 70% of regions have a density of health personnel-to-population per 1,000 that is less than 1.5, indicating a shortage of health personnel. Health facilities in Douala, whether Public, Faith-Based, or private, are characterized by poor working and living conditions (Tandi et al., 2015).

For this study, 11 health facilities were randomly selected for both qualitative and quantitative assessments to evaluate current healthcare waste generation rates and practices. The facilities included five Public hospitals (PU1, PU2, PU3, PU4, and PU5), three Private hospitals (PR1, PR2, and PR3), and three Faith-Based hospitals (FB1, FB2, and FB3). These are not the actual names of the hospitals. All the selected hospitals provide inpatient and outpatient services at different scales, with some categorized as tertiary hospitals. The study was conducted from March to December 2021.

Study design

A cross- sectional study was conducted in each facility to measure health care waste generation rate and describe current management.

Source population and sampling method

Source population for this study was all 11 hospitals which are found in Douala three hospital types. The three hospital types were selected purposively based on ownership while the 11 health care facilities were selected randomly to assess health care waste generation rate and its management system. All departments which are found in these facilities were included in the study.

Data collection tools and procedures

Data were collected through field quantifications/observations, interviews, and questionnaire survey. To quantify the amount of health care waste generated from each unit/facility, measurements were done daily for consecutive 30 days. An observational checklist was used to assess the management system in terms of segregation, collection, transportation, and treatment of health care wastes and how healthcare workers and waste handlers handled healthcare waste in all departments of the hospital. To quantify the amount of health care waste generated unit/facility, the waste was collected, sorted and weighed every day using weighing scale in the mornings (Figure 1) Waste characterization was undertaken by creating waste categories (Table 1) based on an adaptation of the health care wastes categories proposed by the World Health Organization, WHO (Pruss et al., 1999). Appropriate protective equipment (gloves, face masks) were used to manually separate the individual waste bins from each department into separate waste.

Informal interviews and structured questionnaires were used to collect data on waste practices from 335 key hospital staff and stakeholders including general supervisors, sanitation workers, Doctors and nurses who are directly responsible for the handling of various waste streams at individual facilities. The questionnaires were proportionately distributed for the based on the status of the hospitals (PU1=81, PU2=19, PU3=19, PU4=34, PU5=19, PR1= 50, PR2=19, PR3=19, FB1=55, FB2=19, and FB3 19). The questionnaires were designed to obtain information on the characteristics of each facility and the existing procedures and practices in the generation and handling of wastes produced. Observational walks were also undertaken across the entire facility to identify the number of departments, wastes collection, handling and disposal practices at the facility.

Data analysis

The data was subjected to descriptive and inferential analysis, Microsoft excel 2010 and SPSS version 20. Descriptive statistics included the use of, percentages, frequencies, mean, variance and standard deviation. Kruskal Wallis test, ANOVA, factor analysis and simple linear regressions were used to test if there was a significance difference between different units/facilities and ownership type with regard to total health care waste generation rate and types of waste and as models for prediction. Finally, the result was presented using tables, tables, box plots, bar charts, pie charts and graphs.

Data quality assurance

To assure the quality of data collected, assistant data collectors were trained. The weighing scales were calibrated every morning using a known weight before the actual measurements start. Close and routine onsite observation was made by the investigator during the collection and measurement of wastes.

Ethical clearance

Ethical clearance was obtained from University of Buea, through the Faculty of Health Sciences. Permission for data collection was

Figure 1. Sample pictures showing waste collection and weighing.

obtained from the authorities of the different health facilities. All data collectors were reminded and provided protective devises for use while collecting and measuring healthcare wastes

RESULTS

Characteristics of healthcare workers

Table 2 shows the socio demographic characteristics of the respondents. There were more female health workers 230 (60.3%) compared to the males. Majority of the respondents 157 (44.6%) were between the ages of 30 and 39 years. Forty-five percent of participants in the study are in the income range of 101000 – 200000 frs CFA while only 18.4 % earn more than 401000frs a month. Most of the respondents 169(48%) were nurses while the least 29(8.2%) were laboratory scientists. The number of health care workers in the hospitals are in the order of Nurses 169 (48%) > Waste handlers 72 (20%) > doctors 36(10.3%) > lab Technicians/assistants 29(8.2) > health/ward assistants 11(3.1%)> Administrators 4 (1%). Majority of the respondents 169 (48.2%) have been employed for less than 5 years closely followed by 114(30.2) respondents employed for 5 to 10 years. Two hundred and fifteen (61.0%) of the health workers had attained tertiary education with only 12(3.2%) attaining post graduate level of education.

Characteristics of the studied healthcare facilities of in Douala

Three are 1671 beds in the three hospitals categories for inpatient services and short stays (Table 3). A greater proportion (77.7%) of these beds is found in government health facilities, Faith Based (13.3%) and then private (9%) health facilities. Within the 30 days' study period, a total of 29777 outpatients were documented in the hospitals: 21662 (72.8%) at Public Health facilities, 5675 (19.1%) at Faith Based facilities and 2440 (8.2%) at privately owned health units (Table 4). The hospitals received a total of 4985 in patients. A majority (4356 (87.4%) of the in patients were registered in government hospitals while only 359 (7.2%) and 270 (5.4%) were respectively recorded in Faith Based and private health facilities, respectively. The studied establishments record a total number of 2390

Table 1. Description of some terms used in the study.

Waste category	Description
General waste	Domestic type of waste, packing material, wastewater from laundries
Infectious waste	Includes cultures and stocks of infectious agents from laboratories, waste from survey and autopsy on patients in isolation wards and dialysis from infected patients
Pathological waste	Consists of tissues, organs, body parts, human fetuses, blood and body fluids
Sharps	Includes items like needles, blades, broken glass etc. i.e. any item that can cause a cut or puncture
Pharmaceutical wastes	Consists of pharmaceutical products, drug and chemicals those have been returned from the wards

health personnel. In a descending order, the Public hospitals has the greatest (1753 (73.5%)) number of workers followed by the Faith Based 440 (18.4%) and then the private 197(8.2%). The total number of doctors in the government hospitals stands at 181 with an average 30.2 in each hospital.

The private hospitals have an average of 6.7 doctors per hospital while the Faith Based hospitals have an average number of 15.3 doctors per hospitals. The average number of nurses in each hospital type stands in the descending order of Public > Faith Based > private with absolute averages of 140.2, 70 and 31.2 nurses, respectively. The Public hospitals, followed by the Faith Based and then private also consistently dominate in the number of administrators, laboratory technicians, and waste handlers. Apart of the government hospitals, only the FB1 owns an incinerator.

Waste composition and generation rates

Waste generation rates

Within the 30 days period, the highest quantity of waste was generated from the PU4 hospital (615.7 kg), a government owned hospital while the least was generated from a privately-owned hospital, PR2 with a total quantity of 165 kg (Table 4). Comparatively, more waste is generated in Public Hospitals (2257.52 kg) than in Private Hospitals (831.2 kg) and then Faith Based Hospitals (789 kg). For example, more waste was generated in the PR2 with fewer units. Alternatively, the average quantity of waste generated in Public Facilities > Faith Based >Private, with quantities standing at 15.06>9.2>8.8kg, respectively. The summary statistics for pair wise comparison is presented in (Table 5) in which public hospitals waste generation was statistically different ($p= 0.14$, $\alpha =0.05$) from Private and Faith Based facilities (which shows no significant differences amongst them). Government hospitals have higher number of beds, higher outpatient flow and visitors. The quantities of waste generated per bed/day varied from 0.105 to 0.26, 0.06 - 0.164 and 0.11 to 0.22 or Public, Faith Based and Private Facilities respectively. The average rates were as follows: 0.299, 0.184 and 0.129 for Public Private and Faith Based facilities, respectively. For the Public Hospitals, the highest quantity of waste per bed/day (0.105 kg) was generated by the PU5 Hospital. In the private facilities the highest quantity of waste per bed (0.228 kg) was recorded at the PR3 Hospital. On average, in a descending order, more waste is generated per bed per day in public facilities > Private > Faith Based facilities respectively. Patients of government hospitals generate on average 0.087 kg every day while in Faith Based hospitals, averagely 0.74 kg of waste is generated a day.

Figure 1 shows the daily waste generation. On a daily basis, a median quantity of 25.90 kg of waste was generated by private hospitals against 24.5 kg in Faith Based (Figure 2). A very huge quantity of waste was generated by the Public Hospitals in day one (1) and 22 (as represented by the 1 and 22 outliers above the box plot). For the private hospitals, huge quantities were generated on day one and two (represented by the outliers 31 and 32) in Figure 2a. Almost same quantities are generated daily by the different Faith Based hospitals evaluated.

The median quantity of waste generated per bed per day by private hospitals is greater than that generated by Faith Based and public hospitals Figure 2b. These median values stood at 0.22 > 0.19 > 0.09 kg/bed/day respectively for the private, Faith Based and public hospitals. The median quantities of waste generated per patient per day (Figure 2c), stood at 0.31 > 0.11> 0.09 kg/patient per day for private, Faith Based and public hospitals respectively.

Selection of the best fit models for the prediction of hospital healthcare waste generation rate by outpatients

From the linear regression model (Figure 3), used for the prediction waste generation rates by outpatients, R^2 values obtained were in a descending strength of 0.9732, 0.9298, and 0.7275 for Private, Public and Faith Based hospitals respectively. This indicates that the number of outpatient accounts for 97, 92 and 72% of total variance explained in solid waste generation in the hospitals. Out patients thus fairly well predict waste generations.

Table 2. Socio-demographic characteristics of healthcare workers.

Characteristics	Mid-class	Frequency	Percentage
Gender	Male	140	39.7
	Female	213	60.3
	Total	353	100
Marital status	Single	90	25.5
	Married	247	70
	Widow/widower	16	4.5
	Total	353	100
Age group (years)	<20	3	0.8
	20 - 29	71	20.1
	30 - 39	157	44.6
	40 - 49	92	26.1
	50 - 59	28	7.9
	60 - 69	2	0.5
	Total	353	100
Income level (FRS)	<100.00	71	20.1
	101.000 - 200.000	159	45
	201.000 - 300.000	55	15.6
	301.000 - 400. 000	3	0.9
	≥401.000	65	18.4
	Total	353	100
Occupation	Doctor	36	10.3
	Nurse	169	48
	Health/ward asst	11	3.1
	Administrator	4	1
	Lab Tech/Asst	29	8.2
	Waste handlers	72	20.4
	Others	32	9
	Total	353	100
Years of experience	<5	169	48.2
	5 - 10	114	32.3
	11 - 15	28	7.9
	16 - 20	19	5.7
	21 - 25	16	4.4
	26 - 30	7	2.0
	Total	353	100
Level of education	Primary	55	15.5
	Secondary	72	20.3
	Tertiary	215	61.0
	Postgraduate	11	3.2
	Total	353	100

Table 3. Characteristics of the sampled hospitals in Douala.

Facility ownership	Facility name	Total number of beds	Outpatients / month	Inpatients/ month	Total number of patients	Number of staff	Number of incinerators	Doctors	Nurses	Health/w ass	Admin	Lab/tech ass	Waste handlers	Others
Public (Government)	PU1	630	9010	2562	11572	675	1	70	324	21	7	28	165	60
	PU2	150	3103	1006	4109	230	1(bad)	24	110	7	3	18	47	21
	PU3	168	2904	908	3812	208	1(bad)	21	100	6	3	17	42	19
	PU4	230	4340	1340	5680	430	1	44	206	13	5	35	88	39
	PU5	120	2305	1102	4307	210	1	22	101	7	2	17	43	18
Sub-Total		1298 (77.7)	21662 (72.8%)	4356 (87.4%)	29781 (77.3%)	1753 (73.5%)		181 Av= 0.2	841 Av= 140.2	54 Av= 9	20 Av= 3.3	115 Av=19.2	385 Av= 64.2	157 Av= 26.2
Private	PR1	50	106	73	179	37	0	4	17	1	1	3	8	3
	PR2	50	1331	101	1432	90	0	9	43	3	1	7	19	8
	PR3	50	1003	96	1099	70	0	7	34	2	1	6	14	6
Subtotal		150 (9%)	2440 (8.2%)	270 (5.4%)	2710 (7.0%)	197 (8.2%)		20 Av = 6.7	94 Av= 31.2	6 Av= 2	3 Av= 1	16 Av = 5.3	41 Av= 13.7	17 Av= 5.7
Faith Based	FB1	73	1442	151	1593	90	1	10	43	3	1	6	18	8
	FB2	50	2201	98	2299	100	0	10	48	3	1	8	20	10
	FB3	100	2032	110	2142	250	0	26	119	8	3	21	50	23
Sub-total		223 (13%)	5675 (19.1%)	359 (7.2%)	6034 (15.7%)	440 (18.4%)		46 Av 15.3	210 Av= 70	14 Av= 4.7	5 Av= 1.7	35 11.7	88 Av= 29.3	41 Av= 13.7
Grand-Total		1671	29777	4985	38525	2390		247	1145	74	28	166	514	215

Regression models for inpatient and total quantity of waste (kg) in 30 days in the different hospitals

From the linear regression models, R^2 values obtained from hospitals stood in the descending order of 0.724 > 0.3192> 0.1478 for private, Faith Based and public hospitals, respectively (Figure 4). The inpatients do not considerably predict the quantity of waste generated as do the out patients. In patients in private hospitals still produce more waste than in government hospitals.

Quantity of waste generated in the different units in health facilities

Major units with notorious waste generations were as follows the theater > maternity > Medicine C 4 > Radiology > Emergency > Laboratory (Table 6). Among the different types of hospitals, the quantity of waste generated following units waste generations stood in the following order, Medicine C 4 (260 kg)> Theatre (230.9 kg) > Maternity (228.9 kg); Emergency unit (175.3 kg) > Theater (158.7 kg) > Laboratory (119.6 kg) > Maternity (113.9 kg); and the Theatre (153.7 kg) > the

Table 4. Waste generations' rates in the different hospital.

Hospital type	Hospitals	Total Waste (Kg) in 30 days	Total daily weight of waste generated (Kg/day)	Waste generated (Kg/bed/day	Kg/Patient/ day
	PU1	484.72	16.2	0.026	0.042
	PU2	387.7	12.9	0.086	0.094
Public	PU3	389.1	13	0.077	0.102
	PU4	615.7	20.5	0.089	0.108
	PU5	380.3	12.7	0.105	0.088
Total (average)	5	**2257.52 (451.50)**	75.3(15.06)	**0.383 (0.299)**	**0.434 (0.087)**
	FB1 Hospital	344.7	11.5	0.158	0.217
Faith based	FB2	246.8	8.2	0.164	0.106
	FB3 Hospital	197.5	6.6	0.066	0.092
Sub-Total (average)	3	**789 (263)**	26.3 (8.8)	**0.388 (0.129)**	**0.415 (0.138)**
	PR1	324.2	10.8	0.216	1.8
Private	PR2	165	5.5	0.11	0.114
	PR3	342	11.4	0.228	0.308
Sub-total (average)	3	**831.2 (277.1)**	**27.7 (9.2)**	**0.554 (0.184)**	**2.222 (0.741)**

Table 5. Krustal-wallis pair wise comparison for total waste generation in surveyed health facilities in Douala.

Groups comparison	Test statistics	Std. error	P. value
Public facilities	9.4	2.052	0.017[a]
Faith Based facilities	3.6	2.44	0.083[b]
Private facilities	4.3	2.61	0.094[b]

Laboratory (115.7 kg) > the Radiology (112.4 kg for Public, Private, and Faith Based, respectively. The least quantity of waste (82.2 kg) was generating from the Hemodialysis center. None of the private hospitals owns a Covid-19 Unit or a Mortuary and thus no waste generated. Among the Public hospitals, less is generated at the PU1 Hospital when compared to the PU4. Within the private health establishments, waste production per unit is highest at PR3. Among the Faith Based hospitals, unit generation is highest at FB2 Hospital.

Types of waste generated in the Hospitals

A quantitative assessment (Table 7) indicated that a majority of the waste in the different categories was general waste. General waste ranges from 0.17 to 0.32, 0.16 to 0.25, and 0.17 to 0.28 kg/day for the Public, Private and Faith Based facilities, respectively. The quantity of hazardous waste ranges from 40.7 to 81.4%. The percentages show that the average value of the hazardous component of the total healthcare waste was > 50% in the different hospital types. The hazardous waste included Infectious (materials contaminated with blood, cultures and stocks of infectious agents, waste from patients in isolation wards, swabs, bandages, urine faeces and body secretion) Pharmaceutical and Pathological waste such as body parts, chemicals used in pathological activities, needles, syringes expired, used and contaminated drugs and vaccines. Materials used in the handling of pharmaceutical products such as vials, connecting tubing were also generated in these unites, and Sharps. The infectious waste range as follows 0.7 to 0.18, 0.11 to 0.13, and 0.06 to 0.15 kg/day for the Public, Private and Faith Based facilities, respectively. The quantities of sharps ranged from 0.03 to 0.7 for the public, 0.02 to 0.06 for the

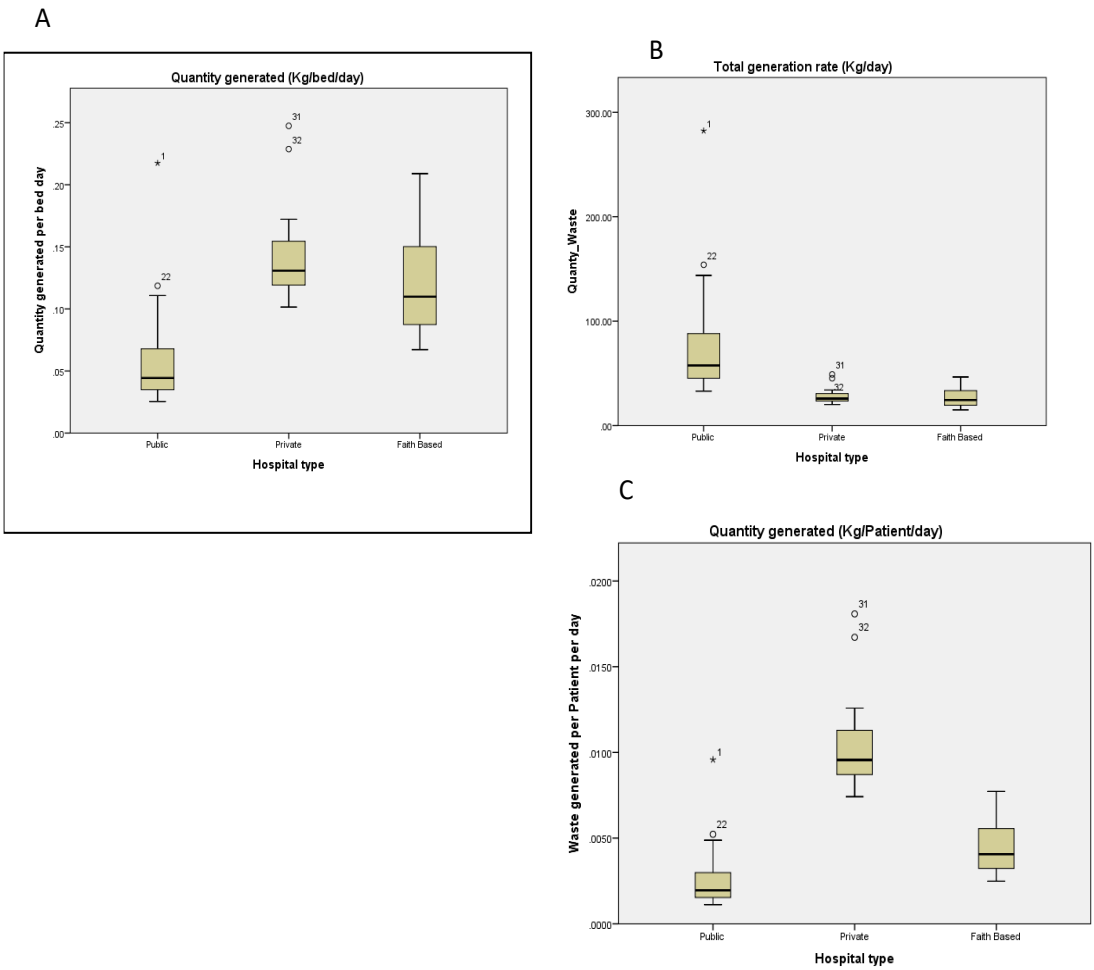

Figure 2. A: Total daily waste generated by the different hospital types; B: Total daily waste generated per bed by the different hospital types; C: Total daily waste generated per patient by the different hospital types.

Private and 0.02 to 0.03 for the Faith Based facilities. More sharps were generated in the public than the other facilities. Pharmaceutical waste ranges from 0.01 to 0.14, 0.03 to 0.06 and 0.05 to 0.07 kg/day respectively for the Public, Private and Faith Based facilities. From one-way analysis of variance, there are a significant difference (0.001<0.05) in the categories of waste generated among different hospitals while there was no (0.323 > 0.05) there was no significant difference in categories of waste generated at different units in hospitals (Table 8).

Perceptions on types of waste generated

The study revealed that in all the hospitals, there were multiple responses regarding perceptions of the types of wastes generated. Many participants indicated that all forms of waste were generated in the hospitals in different perceived proportions of the categories. At least 58.3% perceived the waste generated to be hazardous (infectious, highly infectious, pathological, sharps, pharmaceutical, etc.), while a maximum of 68.7% perceived it to be nonhazardous/nontoxic (Table 9). Observations in some cases revealed general waste mixed with hazardous waste, making them hazardous. Figure 5 shows that in the different types of hospitals, it was perceived that all categories of waste were generated. A chi-square test revealed no evidence of a significant association (P= 0.185, r = 0.05) between the type of hospital and the nature of the waste generated (Table 10). From Principal Component Analysis, two principal factors were extracted explaining the reasons for the nature of waste generated in the hospitals. The two factors explained 43.9% of the total variance. Principal Component One contributed 24.8% of the total variance, while Principal Component Two contributed 19.1% (Table 11).

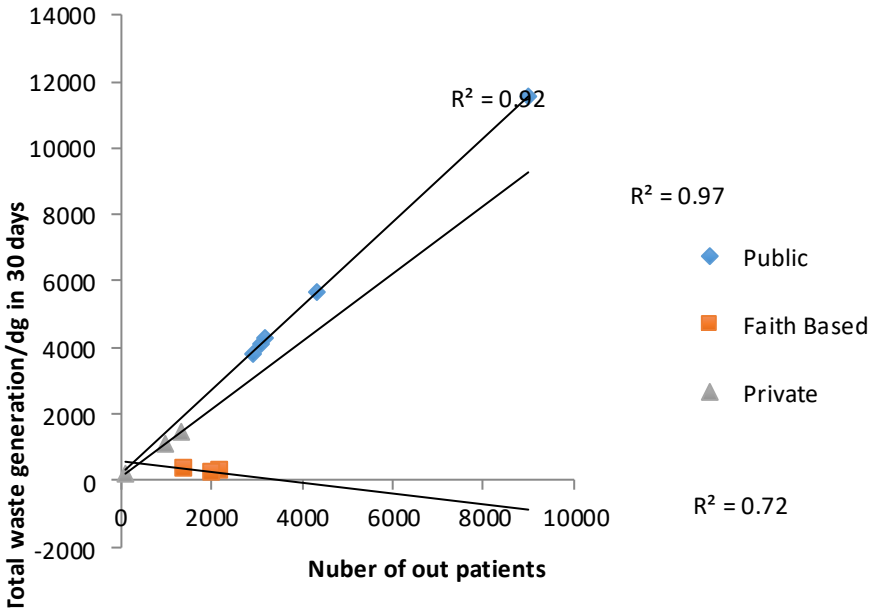

Figure 3. Regression models for outpatient and total quantity of waste (kg) in 30days in the different hospitals.

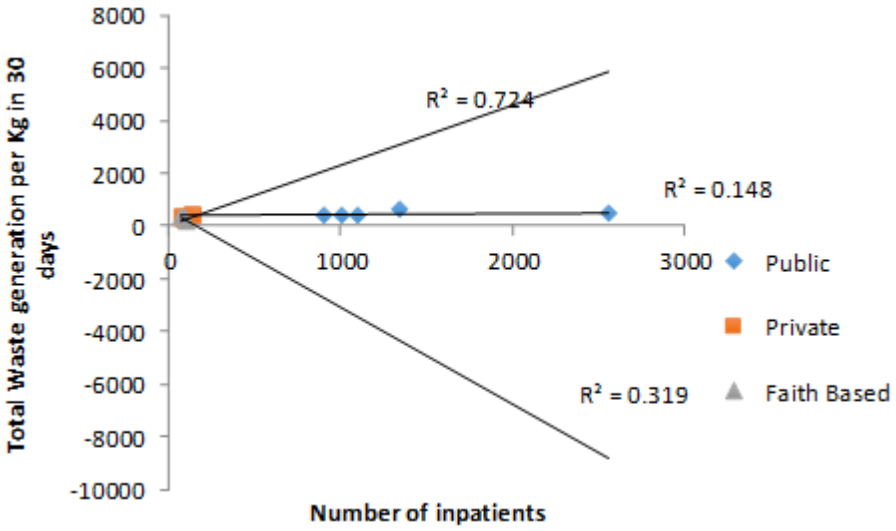

Figure 4. Regression models for inpatient and total quantity of waste (kg) in 30days in the different hospitals.

Factor one *w*as moderately loaded by characteristic such as Follow up on clinical waste to landfill (0.780), Recording of clinical waste data (0.709), Problems in clinical waste management (0.686). *Factor two* comprised of Frequency on clinical waste management training (0.724), units (0.529), which were positively loaded while waste accessible to all persons and scavengers (was negatively loaded). Before Principal component analysis was performed, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the Bartlett's Test of Sphericity were carried out (Table 12). A value of 0.530 was obtained for the Kaiser-Meyer-Olkin Measure of Sampling Adequacy which was low but permits PCA analysis and the Bartlett's Test of Sphericity gave a significant result.

Table 6. Total quantity of waste (/kg) generated in the different units in health facilities in Douala/30 days.

Hospital type	Sampled hospitals	Anapath	COVID-19 unit	Emergency	Hemodialysis	Laboratory	Maternity	Medicine C4	Mortuary	Pharmacy	Purification chamber	Radiology	Theatre
Public	PU1	14.1	13.14	12.2	9.7	9.7	13.1	22.8	10.2	9.2	0	12.7	26.7
	PU2			37		32	61	38.2	21	24		42.7	63.8
	PU3			31.4		34.4	59.4	59.4	29.4	32.1		57.2	41.8
	PU4	28.5	80.64	48.9	27.9	20	46.8	121.8	42.2	42.4	19.8	42.1	38.4
	PU5	12.1		13.4	8.1	4	26.9	17.8	4.2	5.9		8.4	58.2
Sub-total		54.7	93.78	142.9	45.7	100.1	207.2	260	107	113.6	19.8	163.1	228.9
Private	PR1	8.8		82.3	23.1	43.2	32.4	30.6	0	21.1	23.1	2.6	57
	PR2			18		25.4	15.5	5.4		28.8		10.7	44.7
	PR3			75		51	66			39		54	57
Sub-total		8.8		175.3	23.1	119.6	113.9	36		88.9	23.1	67.3	158.7
Faith based	FB1	26.6		13	13.4	38.1	15.6	28.1	25.4	16	19.4	28	35.6
	FB2			23.8		55	48	17.4		19		46	55
	FB3			17.6		22.6	30.1	20		25.7		38.4	63.1
Sub-total		26.6		54.4	36.5	115.7	93.7	65.5	25.4	60.7	19.4	112.4	153.7
Grand total		90.1	93.78	372.7	82.2	335.4	414.8	361.5	132.4	263.2	62.3	342.8	541.3

DISCUSSION

Waste generation rates and composition by health facilities

More waste is generated in public than private and Faith Based health facilities. The quantity of waste generated in hospitals was related to the number of units in those hospitals. For example, more waste was generated in the PU1 hospital and PU4 with more units (15 units each) than in PR1 and PR2 with few units. This result agrees with the findings of Marinkovic et al. (2008) who reported that the amount of HCW production depends on the size and the type of medical institution and differs from country to country based on their national income or their level of development. The higher quantity of waste generated in the PU1 and PU4 could be related to the fact that in these hospitals have more units and would have therefore invested more money in the health system leading to larger amounts of medical waste generation. In this study, within a period of 30 days PU4 hospital generated 615.7 kg of HCW PR2 generated 165 kg. In a study to assess current practices of waste management in teaching hospitals and the presence of incinerators in densely populated area in Pakistan, Khalid et al. (2021) overall higher significant ($P< 0.017$) mean ranks for public hospitals than private.

The average total hospital healthcare waste generation rate estimated in kg/bed/day was 0.164 kg kg/ bed/day in this study is smaller compared with the generation rate in Iran (2004) 2.71

Table 7. Quantitative categories of waste generated in the hospitals.

Hospital type	Hospital	General	Infectious	Sharps	Pharmaceutical	Pathological	Average hazardous (%)
	PU1	0.32±0.01	0.08±0.02	0.7±0.01	0.04±0.01		71.9
	PU2	0.25±0.08	0.18±0.06	0.02±0.01	0.14±0.06	_	57. 6
Public	PU4	0.27±0.02	0.16±0.03	0.03±0.01	0.05±0.01	0.04±0.01	50.9
	PU3	0.18±0.13	0.16±0.06	0.05±0.01	0.06±0.01	0.002±0.001	60 .2
	PU5	0.17±0.03	0.07±0.03	0.03±0.01	0.01±0.006	0.007±0.001	40. 7
	PR1	0.16±0.08	0.11±0.01	0.02±0.01	0.06±0.01	0.009±0.001	55.70
Private	PR2	0.25±0.02	0.16±0.03	0.06±0.01	0.05±0.01	0.04±0.01	52. 4 2
	PR3	0.20±0.02	0.13±0.08	0.06±0.06	0.03±0.005	0.02±0.004	51. 41
	FB1	0.17±0.05	0.06±0.02	0.03±0.004	0.05±0.01	0.04±0.01	43.63
Faith Based	FB2 Hospital	0.22±0.04	0.13±0.09	0.03±0.02	0.05±0.03	0.06±0.03	81.4
	FB3 Hospital	0.28±0.11	0.15±0.10	0.02±0.01	0.07±0.03	0.03±0.02	53.69

Table 8. A comparison of the different categories of wastes generated within and across the different hospital.

ANOVA

		Sum of squares	df	Mean square	F	Sig.
	Between groups	316.649	12	26.387	2.995	0.001
HOSPITAL	Within groups	1965.062	223	8.812		
	Total	2281.712	235			
	Between groups	245.273	12	20.439	1.147	0.323
UNIT	Within groups	3973.117	223	17.817		
	Total	4218.390	235			

Table 9. Nature of waste generated in the hospitals.

Nature of waste	Frequent	Percent
General (Non-hazardous)	206	58.3
Infectious	243	68.7
Highly infectious	162	45.8
Pathological waste	143	54.3
Sharps	62	22.1
Pharmaceutical wastes	113	42.7
Total	353	100

kg/bed/day, UK (3.3 kg/bed/day), Norway (3.9 kg/bed/day) and Kuwait (7.0–10.0 kg/bed/day) as it can be seen in Bdour et al. (2007) (37, 54). The reason for this is the higher the per capita gross domestic product (GDP), the higher quantity of hospital healthcare waste which is related to the high supply and provision of healthcare services. The study conducted in Ethiopia (2011) show a higher waste generation rate range (0.75–10.47 kg/bed/day), but the results of this study are comparable with those reported in Turkey (2010) 2.35 kg/bed/day (31, 58). With the exception of this small discrepancy, the findings are in agreement with the fact that in developing countries the overall healthcare waste generation rate is smaller than in developed nations. As the healthcare delivery system of the country is similar across the regional states, the findings of this research may serve for all hospitals

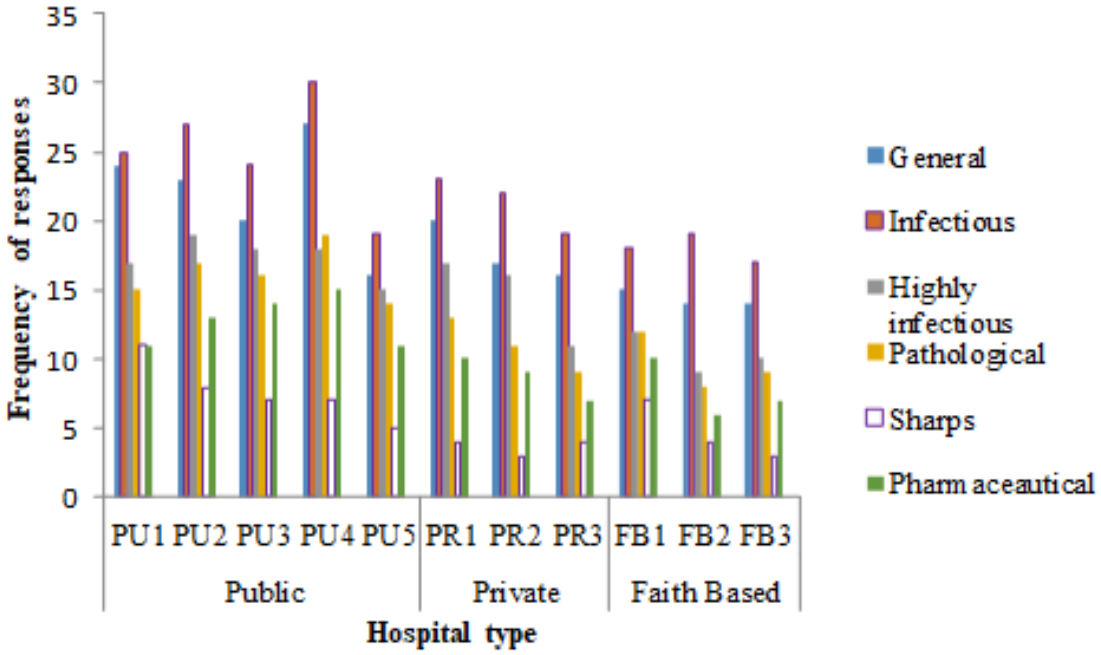

Figure 5. Nature of waste generated per hospital type.

Table 10. Chi-squate test of association between nature of waste generated and type of hospital.

Chi-Square Tests			
	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	11.313[a]	8	0.185
Likelihood Ratio	11.462	8	0.177
Linear-by-Linear Association	0.479	1	0.489
N of Valid Cases	310		

Table 11. Component matrix for two principal components extracted explaining quantities of waste produced.

Component matrix	**Component**	
	1	**2**
Follow up on clinical waste to landfill	0.780	0.327
Recording of clinical waste data	0.709	0.033
Problems in clinical waste management	0.686	-0.303
Hospital	0.454	0.007
Quantity of clinical waste generated kg per day	0.420	-0.182
Frequency on clinical waste management training	0.110	0.724
Waste accessible to all persons and scavengers	0.097	-0.709
Unit	-0.015	0.521
Total variance explained		
Total	1.985	1.531
% of variance	24.808	19.134
Cumulative %	24.808	43.942

Table 12. Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity prior Principal component analysis.

Kaiser-Meyer-Olkin measure of sampling adequacy		**0.530**
Bartlett's Test of Sphericity	Approx. chi-square	233.425
	Df	28
	Sig.	0.000

in similar settings. The generation rates of total number of patients (in and outpatient) estimated in kg/patient/day was not significantly different when compared between private and government hospitals. On the contrary, the generation rates of inpatients estimated in kg/bed/day were significantly higher in private hospitals than government hospitals. This is owing to the fact that patients who have access to private hospitals have high incomes and can make a significant contribution to the generation rate of healthcare waste.

US hospitals generate an estimated 6,670 tons of healthcare waste per day (Rutala and Mayhall, 1992), 3,8 kg/bed/day in Portugal (Alvim-Ferraz et al., 2000) and 1 kg/bed/day is generated in Thailand (Kerdsuwan, 2000). This indicates that the quantity of waste generated per bed per day in hospitals in Douala is far less that that generated in the Developed countries. This could be related to the unavailability of medical equipment's and/or the inability of patients to purchase requested materials. Marinkovic´ et al. (2008) had earlier reported that highly developed countries have a larger production of medical waste than middle developed and developing countries. More waste is generated by inpatients in private hospitals, than other hospitals which could be related to the fact than a majority of those who make use of private hospitals are the economically viable individuals who can afford to pay for all services demanded. A study conducted in Jordan (2007) confirmed that there was high statistically significant (linear) correlation between the number of inpatients and the amount of daily healthcare waste generated. The hospital waste generation prediction models can help to optimize healthcare waste management systems, set guidelines and evaluate the prevailing strategies for healthcare waste handling as well as disposal.

Nature of waste generated in the Hospitals

The highest quantity of infectious waste generated varied with hospital type. This variation is highly influenced by the management of noninfectious waste as it mixing with hazardous waste makes it to become hazardous. According to OTA (1992) it is also challenging to determining which portion or components of healthcare waste is infectious due to its inherent heterogeneous nature and definitional problems. Furthermore, no tests currently exist to objectively determine whether waste is infectious or not (Rutala and Mayhall, 1992). This might have affected the quantities of infectious wastes reported by the hospitals. Chi-square test revealed no evidence of a significant association ($P = 0.185$, $r = 0.05$) between the type of hospital and the nature of the waste generated. This means that all hospitals generated similar types of wastes. Within the hospitals, the highest quantities of waste generated (12.9 %) comes from the Laboratory s Sakear et al. (2006) similarly pointed out that in Bangladesh, Laboratories and diagnostic centers produce the highest quantities of HCW.

From Principal Component Analysis, the two principal factors that were extracted explained only 43.9 % of the total variance. This indicates that HCW in Douala is much more complex than to be totally explained by the variables considered in this study. Those who followed up the clinical waste to landfill, Frequency on clinical waste management training, just as recording of clinical waste data daily generated more wastes. This ensures proper management. According to WHO (2011) poor management of health care waste potentially exposes health care workers, waste handlers, patients and the community at large to infection, toxic effects and injuries, and risks polluting the environment. It is essential that all medical waste materials are segregated at the point of generation, appropriately treated and disposed of safely.

Categories of waste generated in the hospitals

The proper management of waste generated in medical facilities depends to a large extent on strong knowledge on the type of waste generated, the administration and organization of the health facilities concerned. From the results a quantity of hazardous waste ranges from 43.63 to 81.4%. According to a WHO report, around 85% of the hospital wastes are actually non-hazardous or general wastes, and the remaining 10-25% is hazardous in nature (Mukesh, 2001). However, the result from these hospitals identified that of total stream of health care wastes was lower than hazardous. This result was comparable with a result obtained in Nigeria where 41% of the total health care waste generated was hazardous (Ogbonna, 2013). But it was much bigger than a result identified in Sudan where only 20% of the total health care waste stream

generate are hazardous (Ahmed et al., 2014). This could be attributed to inappropriate segregation practice of health care wastes generated in the hospital.

Conclusion

More waste is generated in Public Hospitals (2257.52 kg) than in Private Hospitals (831.2 kg), with Faith-Based Hospitals generating even less (789 kg). Specifically, Public Hospital PU1 dominated in generating the highest quantity of infectious waste, while private hospitals produced the least infectious waste. Figure 1b illustrates that the median quantity of waste generated per bed per day in private hospitals is greater than that in Faith-Based and Public hospitals. These median values are 0.22 > 0.19 > 0.09 kg/bed/day, respectively, for private, Faith-Based, and public hospitals. Similarly, the median quantities of waste generated per patient per day are 0.31 > 0.11 > 0.09 kg/patient per day for private, Faith-Based, and public hospitals, respectively.

Interestingly, inpatients do not significantly influence the quantity of waste generated compared to outpatients. Linear regression models show R2 values in the order of 0.724 > 0.3192 > 0.1478 for private, Faith-Based, and public hospitals, respectively.

The major units with notorious waste generation, in descending order, are the theater, maternity, Medicine C 4, Radiology, Emergency, and Laboratory. The total hazardous waste generated in this study surpasses the nonhazardous waste, aligning with expectations for healthcare facilities in developing countries. However, the magnitude of hazardous waste generated exceeds the estimate set by the World Health Organization (WHO).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors are grateful for the support given by the different hospital authorities.

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