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Assessment of healthcare costs of amputation and prosthesis for upper and lower extremities in a Qatari healthcare institution: a retrospective cohort study

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ABSTRACT

Objectives To evaluate the healthcare cost of amputation and prosthesis for management of upper and lower extremities in a single institute.

Design Retrospective cohort study conducted between 2000 and 2014.

Participants All patients who underwent upper (UEA) and lower extremities amputation (LEA) were identified retrospectively from the operating theatre database. Collected data included patient demographics, comorbidities, interventions, costs of amputations including hospitalisation expenses, length of hospital stay and mortality.

Outcome measures Incidence, costs of amputation and hospitalisation according to the level of the amputation and cost per bed days, length of hospital stay and mortality.

Results A total of 871 patients underwent 1102 (major 357 and minor 745) UEA and LEA. The mean age of patients was 59.4±18.3, and 77.2% were males. Amputations were most frequent among elderly (51.1%). Two-third of patients (75.86%, 95% CI 72.91% to 78.59%) had diabetes mellitus. Females, Qatari nationals and non-diabetics were more likely to have higher mean amputation and hospital stay cost. The estimated total cost for major and minor amputations were US$3 797 930 and US$2 344 439, respectively. The cumulative direct healthcare cost comprised total cost of all amputations, bed days cost and prosthesis cost and was estimated to be US$52 126 496 and per patient direct healthcare procedure cost was found to be US$59 847. The total direct related therapeutic cost was estimated to be US$26 096 046 with per patient cost of US$29 961. Overall per patient cost for amputation was US$89 808.

Conclusions The economic burden associated with UEA and LEA-related hospitalisations is considerable. Diabetes mellitus, advanced age and sociodemographic factors influence the incidence of amputation and its associated healthcare cost. The findings will help to showcase the economic burden of amputation for better management strategies to reduce healthcare costs. Furthermore, larger prospective studies focused on cost-effectiveness of primary prevention strategies to minimise diabetic complication are warranted.

Strengths and limitations of this study

- ► Large sample of patients who underwent upper and lower extremities amputation.
- ► This study used microcosting and case-mix group methods for healthcare cost analysis.
- ► There is a lack of information about the cost of outpatient care and rehabilitation services.
- ► All amputations were performed in the only tertiary centre in Qatar (2000–2014).
- ► The study focused mainly on diagnostic and therapeutic costs but did not include indirect costs.

INTRODUCTION

Limb amputation remains a major problem worldwide in spite of the advancement in the diagnostic and therapeutic measures. In the USA, 1.6 million people were estimated to be living with limb loss in 2005, of them 65% had lower extremity amputation (LEA).[1] However, upper extremity amputation (UEA) is relatively rare (8%) and mostly related to traumatic injury (68.6%).[1]

According to the recent WHO estimates, around 150 million individuals are affected by diabetes mellitus (DM) globally; and this figure is expected to be twofold by the year 2025.[2] The risk of LEA is considerably higher (10-fold) in patients with DM as compared with non-diabetics.[3] Nearly, 75% of the LEAs are performed in the patients with diabetic foot disease.[4 5] Also, LEA is associated with higher risk of mortality, impaired quality of life and increased healthcare costs among diabetics.[6] Early initiatives perused the goal to reduce the number of LEAs in patients with diabetes.[7 8] However, epidemiological studies have shown marked variations in the incidence, relative risks and time trends and management of LEA in diabetic compared with non-diabetic population,

owing to differences in study design and methodological approaches.[5 9]

Furthermore, the treatment strategies of LEA should carefully account for the associated complications, quality of life and healthcare cost. Lower Extremity Assessment Project study revealed similar functional outcomes in patients underwent amputation or reconstruction of the limb-threatening lower extremity injury.[10] An earlier meta-analysis, based on nine observational studies also found no significant difference in terms of functional outcome of patients with leg-threatening injuries treated either with limb salvage or primary amputation on follow-up.[11] It has been suggested that the functional outcomes are often improved after successful limb reconstruction in comparison to early amputation and appropriate prosthesis.[12 13] Also, some studies concluded that the cost of amputation is less as compared with limb salvage and early amputation is a reasonable cost-effective strategy.[11 14] Although, reconstructive limb salvage is technically challenging and time-consuming, some investigators suggested that it is associated with improved quality of life and lesser costs of treatment as compared with amputation.[15 16] Notably, in Qatar the prevalence of diabetes is rapidly increasing with an escalating problem of diabetic foot disorder that necessitates amputation.[17] Currently, there is a lack of integrated facility to treat diabetic foot ulceration which may compromise the quality of life, with lower productivity, higher medical cost and unnecessary amputations. Therefore, cost of illness (COI) analysis for diabetics and non-diabetics is imperative to provide the scientific evidence for making appropriate clinical decisions, cost-saving and resource allocation. In addition, it could be beneficial for improvement in preventative diabetic foot care, avoidance of unfavourable outcomes and will be a basis for formulation of health policies and fiscally sound decisions to improve healthcare facilities. Considering the expanding need and limitation of healthcare resource, this study presents the healthcare costs of amputation and prosthesis for management of upper and lower extremities in a tertiary healthcare institution of Qatar.

METHODS

Study population and settings

It was a retrospective cohort study based on data obtained from the operating theatre database and medical records at Hamad General Hospital (HGH) for all patients who underwent UEA and LEA between 2000 and 2014. Median follow-up time was 19 with an IQR of 3–53 months. All patients with major and minor amputation were included in the study. Primary healthcare and tertiary referral care centres comprised the healthcare system in Qatar. HGH is the referral hospital that provides basic healthcare facilities to manage high-risk patients for amputation who require elective and emergency surgery including trauma and vascular management. During the study period, there was no provision of health insurance scheme and all emergency services were provided free of cost to patients. Both nationals and expatriates with valid resident permit used to have equal access to health facilities. All in-hospital diagnostic and therapeutic services are available free of charge at HGH for all nationals and residents in Qatar, whereas costs of prosthesis are covered by private or charity agencies for residents. HGH is the only tertiary hospital in Qatar performing amputations during the study period.

Data collection

Data were collected on patient demographic characteristics (age, gender and nationality), DM status, intervention details (indications, level of amputation, major and minor amputation) and part (limb or digit) amputated, length of hospital stay and early mortality. We obtained data for the cost of amputation and hospitalisation according to the level of the amputation (toe, finger, forefoot/hind foot, above/below knee, wrist level, above/below elbow) and cost per bed days. The procedure and material cost was included in the level of amputation cost.

The sessions were categorised as major amputations, which involved below-knee and above-knee amputation, whereas minor amputations referred to the sessions involving digit (toe or finger) and transmetatarsal amputations. Amputations were further classified based on involvement of single or multiple extremities. The major indication for amputation was diabetic foot ulcer with or without ischaemia followed by traumatic injury and tumour. The diagnosis of DM was considered based on patient's history of diabetes and/or current antidiabetic management such as insulin therapy and oral hypoglycaemic agent.

Patient and public involvement

Patients and public were not involved in this study, because it is a retrospective cohort study and data were collected anonymously.

Cost analysis

COI studies are needed for justification of budget, establishment of preventive and interventional programmes and setting up priorities for research funding by healthcare policy makers.[4 5] Depending on the objective of cost analysis, it can be either based on prevalence or incidence of the disease. Prevalence is more commonly considered for budget planning and decision making by health policy makers.[18] This includes calculation of total costs for a study population over particular period of time in a specified area.[18 19] For health economics research, medical costs and disease-associated costs are the two main criteria considered for cost evaluation.[19 20] These medical costs are further subclassified as direct (types of payments and expenses) and indirect (resource utilisation).[19 20] The direct cost involves costs incurred for in-hospital and outpatient services, medical supplies, laboratory investigations, medication, rehabilitation services at care centres, home and caregiver costs. Costs

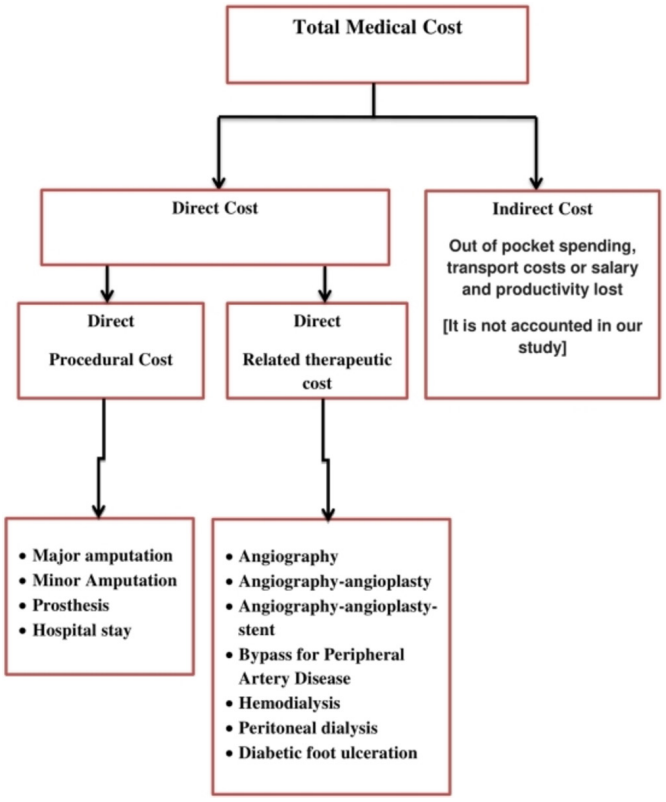

Figure 1 Overview of total medical cost analysis flow diagram.

Table 1 Estimated cost of service—summary

Procedure	Cost (in US$)
Level of amputation	
Toe	2068
Finger	2169
Forefoot/hind foot	10639
Above/below knee	10639
Wrist level	10639
Above/below elbow	10639
Per bed days	1236
Prosthesis	
Prosthesis fabrication	6415
Fitting of prosthesis and training	736.3
Total cost for prosthesis	7151
Therapeutic	
Angiography	684
Angiography-angioplasty	1033
Angiography-angioplasty-stent	2398
Bypass for peripheral artery disease	3115
Diabetic foot ulceration	553845
Haemodialysis	341
Peritoneal dialysis	640

of resources that are lost due to morbidity and mortality referred as indirect costs.[19]

Overall cost=amputation cost+hospital stay cost+prosthesis cost+angiography alone cost+angiography/angioplasty cost+angiography/angioplasty/stent cost+bypass for peripheral artery disease cost+diabetic foot ulceration cost+haemodialysis cost+peritoneal dialysis cost.

The cost of amputation and hospitalisation were calculated using a microcosting methodology, whereas the prosthesis and therapeutic cost were calculated using case-mix group method. This study includes all amputation cases data from a national tertiary centre for a period of 14 years. It also addresses an overview of the clinical progress of a 14-year amputee population. By following this cohort from their initial procedure until rehabilitation, leaving the country or mortality, it provides the reader with valuable insights into the demographic pattern, risk factors, clinical presentation, economic burden, management and outcomes.

Evaluation of amputation costs

The total medical cost of upper and lower limb amputation was calculated by multiplying the number of amputations, hospital stays, prosthesis and therapeutic interventions with the respective unit costs. Figure 1 shows the overview of total medical cost analysis. The direct medical costs were also computed for amputations, hospital stays and prosthesis. The direct related (therapeutic) medical cost evaluation in this study mainly comprised procedural cost involving angiography, angiography/angioplasty, angiography/angioplasty/stent, bypass for peripheral artery disease, management cost of diabetic foot ulceration, haemodialysis and peritoneal dialysis. All costs are represented in US dollars.

The institutional medical cost was obtained from the '*Estimated Cost of Service—Summary*', cost accounting section, finance department, Hamad Medical Corporation, Doha, Qatar (table 1).

Data management and statistical analysis

Descriptive and inferential statistics were applied for data analysis. Cost estimates are presented as point estimates with 95% CIs, which were used to generalise the percentages. Linear regression analysis and scatter plot were used to find out the correlation between variables. Data were analysed using R V.3.5.1 and Statistical Package for the Social Sciences (SPSS) for Windows V.21.0 (SPSS, Chicago, Illinois, USA).

RESULT

Sociodemographic characteristics

A total of 871 patients underwent 1102 (major 357 and minor 745) upper and lower extremities amputation over the 14-year study duration. The mean age of patients was 59.4±18.3, 77.2% (95% CI 74.25 to 79.82) were males and 37.4% were citizens (table 2). Amputations were most frequent in the age group >60 years (51.1%) followed by 41–60 years (33.2%) and ≤40 years (15.7%). The majority of patients (75.9%, 95% CI 72.91% to 78.59%) were

Table 2 Comparison of amputation and hospital stay cost stratified by demographics, aetiology and early mortality (n=871) in US$

Age group (years)	n (%)	Total amputation cost	Mean (95% CI)	Total hospital stay cost	Mean (95% CI)
≤40	137 (15.7%)	882 090	6439 (5662 to 7215)	5 378 984	39 263 (31 984 to 46 542)
41–60	289 (33.2%)	1 678 534	5808 (5128 to 6488)	11 503 434	39 804 (35 327 to 44 281)
>60	445 (51.1%)	3 581 747	8049 (7435 to 8663)	28 572 528	64 208 (45 873 to 82 543)
Gender					
Female	199 (22.8%)	1 589 342	7987 (7114 to 8859)	10 389 560	52 209 (34 804 to 69 614)
Male	672 (77.2%)	4 553 028	6775 (6311.9 to 7239)	35 065 385	52 181 (40 787 to 63 424)
Nationality					
Non-Qatari	545 (62.6%)	3 330 736	6112 (5635 to 6588)	25 933 104	47 584 (35 773 to 59 394)
Qatari	326 (37.4%)	2 811 634	8625 (7902 to 9348)	19 521 841	59 883 (43 415 to 76 088)
Diabetes					
No	210 (24.1%)	1 524 925	7262 (6553.6 to 7970)	10 620 742	50 575 (35 498 to 65 652)
Yes	661 (75.9%)	4 617 445	6985 (6494 to 7478)	34 834 203	52 699 (40 924 to 64 323)
Early mortality					
No	822 (94.4%)	5 571 740	6778 (6361 to 7196)	42 737 637	51 992 (42 005 to 61 856)
Yes	49 (5.6%)	570 630	11 646 (10 099 to 13 192)	2 717 308	55 455 (18 509 to 92 402)
Aetiology					
Diabetic foot	485 (55.7%)	2 931 285	6043 (5546 to 6542)	24 795 742	51 125 (36 743 to 65 507)
Ischaemia	49 (5.6%)	400 219	8168 (6662 to 9674)	2 664 148	54 370 (38 091 to 70 649)
Injury	165 (18.9%)	1 171 397	7099 (6346 to 7853)	6 963 874	42 205 (34 177 to 50 234)
Diabetic foot and ischaemia	166 (19.1%)	1 578 003	9506 (8271 to 10 741)	10 757 967	64 807 (38 704 to 90 910)
Tumour	4 (0.5%)	48 759	12 190 (0 to 27 620)	176 786	44 196 (3329 to 85 064)
Congenital deformity	1 (0.1%)	10 639	10 638	48 214	48 214
Lizard bite	1 (0.1%)	2068	2068	48 214	48 214

diabetics. The most common indication for amputation was diabetic foot complications (74.8%), followed by trauma (18.9%) and ischaemia (5.6%).

Cost analysis

Analysis of the cost of amputation and hospital stay stratified by sociodemographic factors, aetiology and early mortality are shown in table 2. The total and mean amputation and hospital stay cost were highest for elderly patients (>60 years) as compared with other age groups. However, females, Qatari nationals and patients with no diabetes were more likely to have higher mean amputation and hospital stay cost even though the total cost was more in their counterparts. Also, early mortality accounted for higher mean cost of amputation and hospital stay but the total cost for both was relatively lower as compared with those who survived.

Table 3 shows analysis of the cost of amputation according to level of amputation. A total of 357 patients underwent major amputations in the index admission and on follow-up with an estimated total cost of US$3 797 931 and 745 patients required minor amputations which were estimated to cost US$2 344 439. As per the level of amputation, below-knee (n=172) and above-knee (n=164) amputations involved in maximum cost with a total estimate of US$1 829 815 and US$1 744 708, respectively.

Table 4 represents the estimated cost of hospital stay according to the level of amputation. For major and minor amputations, the hospital cost was estimated to be US$21 351 511 and US$24 103 434, respectively. Toe amputations incurred maximum total cost (US$21 454 121) followed by above-knee (US$13 778 159) and below-knee (US$6 815 522) amputations.

The cumulative direct healthcare cost comprised the total cost of all amputations US$6 142 370 (mean: 7052; 95% CI 6642 to 7462), total bed days cost US$45 454 945 (mean: 52 187; 95% CI 42 618 to 61 756) and total prosthesis cost (n=74) US$529 181. Therefore, the total direct healthcare cost was estimated to be US$52 126 496, and per patient direct healthcare cost was found to be US$59 846.

Table 5 represents the estimated total cost (amputation cost+hospital stay cost) according to the level of amputation. For major and minor amputations, the hospital cost was estimated to be US$25 149 442 and US$26 447 873, respectively.

Table 3 Analysis of cost of amputation according to level of amputation in the index admission and on follow-up in US$

Follow-up	First admission			Second admission			Third admission			Fourth admission			Fifth admission			Sixth admission			Seventh admission			
Level of amputation	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	Total
Toe (n=671)	573	1 330 060	2322	71	169 609	2389	19	57 915	3048	6	12 410	2068	2	4136	2068	–	–	–	–	–	–	1 574 132
Forefoot (n=68)	39	414 900	10 639	15	159 577	10 639	10	106 385	10 639	3	319 159	10 639	–	–	–	1	10 639	10 639	–	–	–	723 415
Hind foot (n=4)	4	42 554	10 639	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42 554
Below knee (n=172)	118	1 255 339	10 639	37	393 623	10 639	7	74 469	10 639	6	63 831	10 639	3	319 157	10 639	–	–	–	1	10 639	10 639	1 829 815
Above knee (n=164)	114	1 212 785	10 639	40	425 539	10 639	4	42 554	10 639	4	42 554	10 639	2	21 277	10 639	–	–	–	–	–	–	1 744 708
Finger (n=2)	2	4339	2170	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4339
Wrist level (n=6)	6	63 831	10 639	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	63 831
Below elbow (n=5)	5	53 192	10 639	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	53 192
Above elbow (n=10)	10	106 385	10 639	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	106 385
Type of amputation																						
Major amputation (n=357)	253	2 691 531	10 639	77	819 162	10 639	11	1 170 239	10 639	10	106 385	10 639	5	531 927	10 639	–	–	–	1	10 639	10 639	3 797 931
Minor amputation (n=745)	618	1 791 852	2900	86	329 186	3828	29	164 300	5666	9	44 326	4925	2	4137	2069	1	10 639	10 639	–	–	–	2 344 439
Total (n=1102)	871	4 483 383		163	1 148 348		40	2 813 239		19	150 710		7	57 329		1	10 639		1	10 639		6 142 370

Table 4 Comparison of cost of hospital stays for amputation according to level of amputation in the index admission and on follow-up in US$

Follow-up	First admission			Second admission			Third admission			Fourth admission			Fifth admission			Sixth admission			Seventh admission			
Level of amputation	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	Total
Toe (n=671)	573	19 191 758	33 493	71	1 509 478	21 260	19	561 264	29 540	6	164 423	27 404	2	27 198	13 599							21 454 121
Forefoot (n=68)	39	1 485 989	38 102	15	615 659	41 044	10	182 967	18 297	3	140 934	46 978				1	6181	6181				2 431 731
Hind foot (n=4)	4	186 676	46 669																			186 676
Below knee (n=172)	118	5 671 978	48 068	37	823 352	22 253	7	76 648	10 950	6	179 258	29 876	3	54 396	18 132				1	9890	9890	6 815 522
Above knee (n=164)	114	12 507 280	109 713	40	1 084 203	27 105	4	87 775	21 944	4	39 560	9890	2	59 341	29 670							13 778 159
Finger (n=2)	2	30 907	15 453																			30 907
Wrist level (n=6)	6	233 654	38 942																			233 654
Below elbow (n=5)	5	217 582	43 517																			217 583
Above elbow (n=10)	10	306 593	30 659																			306 593
Total (n=1102)	871	39 832 418	45 732	163	4 032 692	24 740	40	908 654	22 717	19	524 176	27 588	7	140 934	20 134	1	6181	6181	1	9890	9890	45 454 945
Type of amputation																						
Major amputation (n=357)	253	18 937 088	74 850	77	1 907 555	24 773	11	164 423	14 948	10	218 819	21 882	5	113 736	22 747	0			1	9890	9890	21 351 511
Minor amputation (n=745)	618	20 895 330	33 811	86	2 125 137	24 711	29	744 231	25 663	9	305 357	33 929	2	27 198	13 599	1	6181	6181	0			24 103 434

Table 5 Analysis of total cost (amputation+hospital stay) according to level of amputation in the index admission and on follow-up in US$

Follow-up	First admission			Second admission			Third admission			Fourth admission			Fifth admission			Sixth admission			Seventh admission			
Level of amputation	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	n	Total	Mean	Total
Toe (n=671)	573	20521818	35815	71	1679087	23649	19	619179	32588	6	176833	29472	2	31334	15667							23028253
Forefoot (n=68)	39	1900889	48741	15	775236	51683	10	289352	28936	3	460093	57617				1	16820	16820				3155146
Hind foot (n=4)	4	229230	57308																			229230
Below knee (n=172)	118	6927317	58707	37	1216975	32892	7	151117	21589	6	243089	40515	3	373553	28771				1	20529	20529	8645337
Above knee (n=164)	114	13720065	120352	40	1509742	37744	4	130329	32583	4	82114	20529	2	80618	40309							15522867
Finger (n=2)	2	35246	17623																			35246
Wrist level (n=6)	6	297485	49581																			297485
Below elbow (n=5)	5	270774	54156																			270775
Above elbow (n=10)	10	412978	41298																			412978
Type of amputation																						0
Major amputation (n=357)	253	21628619	85489	77	2726717	35412	11	1334662	25587	10	325204	32521	5	645663	33386	0			1	20529	20529	25149442
Minor amputation (n=745)	618	22687182	36711	86	2454323	28539	29	908531	31329	9	349683	38854	2	31335	15668	1	16820	16820	0			26447873
Total (n=1102)	871	44315801	45732	163	5181040	24740	40	3721893	22717	19	674886	27588	7	198263	20134	1	16820	16820	1	20529	20529	51597315

Table 6 Direct related therapeutic interventions cost of amputation in US$

	Cost	Frequency (n)	Total length of hospital stay (days)	Total cost
Therapeutic interventions				
Angiography alone	684	86	–	58 824
Angiography-angioplasty	868	70	–	60 760
Angiography-angioplasty-stent	2398	9	–	21 582
Bypass for peripheral artery disease	3115	55	–	171 325
Diabetic foot ulceration	55 385	444	–	24 590 940
Haemodialysis	341	132	5291	515 495
Peritoneal dialysis	640	25	1058	677 120
Total	–	–	–	26 096 046

Table 6 demonstrated the estimation of direct related therapeutic interventions cost of amputation. The total direct related therapeutic interventions cost was estimated to be US$26 096 046. Haemodialysis (US$515 495), management of diabetic foot ulceration (US$24 590 940) and peritoneal dialysis (US$677 120) accounted for the major direct therapeutic cost.

Regression analysis

Overall cost=36 458.27+1.02 hospital stay cost

There was a positive strong correlation between overall cost and hospital stay cost (r^2=0.96, p=0.00001). Other variables showed a weak correlation (r^2<0.30). Hospital stay cost was an independent predictor of overall cost. Figure 2 depicts the correlation between overall cost and the regression adjusted predicted value.

DISCUSSION

To the best of our knowledge, this is the first study on healthcare cost associated with amputation and prosthesis in the Arab Middle East region. We estimated the association between patient demographics, characteristics, DM, mortality and direct medical costs of upper and lower extremities amputation managed at a tertiary care institution over 14 years. Despite some limitations, the present study attempts to estimate the economic burden of extremity amputation on the healthcare system. The study revealed that the total direct healthcare cost of amputation per patient in Qatar was US$89 808. The expected management cost is considerable and varies according to patients characteristics.

In the present study, the mean age of patients was 59 years and amputations were performed mostly among the elderly group. Prior population-based studies reported a mean age of 65 years in patients with LEA.[21 22] Moreover, females, Qatari nationals and patients with no diabetes were more likely to have higher mean amputation and hospital stay cost in our study cohort; however, the total cost of amputation and hospital stay remains higher among males, non-Qataris and diabetics. Lefebvre and Chevan[23] suggested that females were more likely to undergo major amputation than males which could be attributed to delayed presentation of women with vascular disease. Furthermore, female usually have a longer time for the diagnosis of DM, and its associated complications which might result in higher costs.[24]

The current analysis extends the previous results to demonstrate that the total costs are higher in patients with DM than patients with no diabetes.[25]

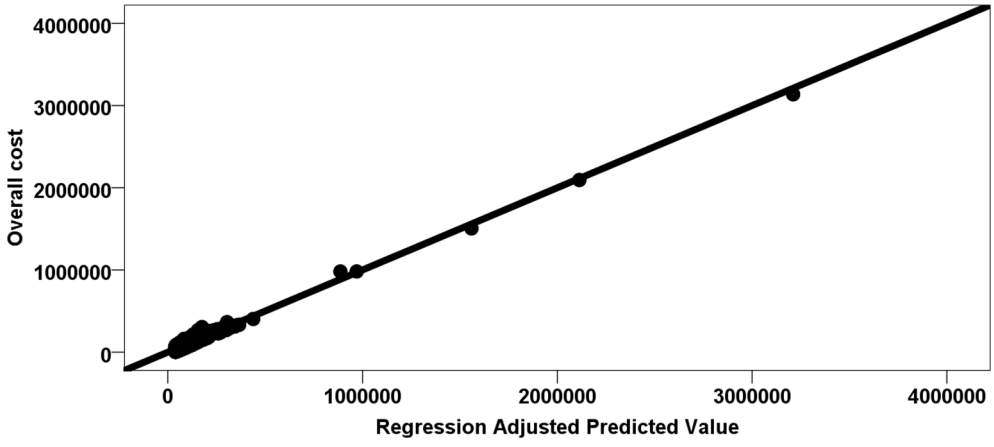

Figure 2 Scatter plot of the overall cost and regression adjusted predicted value.

The global incidence of LEA has dispersion because of population heterogeneity. Even though there is a declining trend over time but the incidence rate of LEA remains high. In our study, 67% of amputations were minor in nature. Globally, there exists a higher incidence of LEA among diabetics which ranges from 46.1 to 9600 per 100 000 population than those without DM (5.8–31 per 100 000 population).[26] Similarly, our study showed that the majority of amputations were done in patients with diabetes (75.86%, 95% CI 72.91% to 78.59%). An earlier study reported a high prevalence of DM (16.7%) in adult Qatari population.[27] In our study, the mean amputation cost was US$6985 and mean hospital stay cost was US$52 699 among diabetics. Brandle *et al*[28] found the median cost of an amputation as US$37 600 (US$23 300–US$62 200) in 2003. The present study reported a higher overall total direct healthcare cost of amputation per patient which was found to be US$59 846. Similar to our estimates, Margolis *et al*[29] reported that the mean total annual Medicare payments for any beneficiary with diabetes-related LEA were roughly US$52 000 in 2008. Rinkel *et al*[30] study on patients with diabetic foot disease, revealed an average in-hospital costs to be US$10 827 (range: 702–82 880) per episode. The average cost of single minor amputation, multiple minor amputations and major amputations were US$13 580, US$31 835 and US$73 813 per episode, respectively. Mundell *et al*[31] identified the mean medical costs for transfemoral amputations of hospitalised patients as US$25 652 (95% CI US$10 468 to US$38 872) and emergency department as US$18 091 (95% CI US$7820 to US$57 368). Franklin *et al*[32] reported in a study that mean cost of care for patients with diabetes in US veterans with lower limb amputation for all amputation level was US$60 647 (95% CI US$59 143 to US$62 188), for toe was US$41 484 (95% CI US$40 075 to US$42 943), below knee was US$71 067 (95% CI US$68 449 to US$73 785) and above knee was US$82 758 (US$78 063 to US$87 736).

Table 7 shows the prevalence of DM in the Arab Middle Eastern region ranges from 1.88% to 25.5%.[27 33–65] Diabetes-related complications could be serious and necessitate prolonged hospitalisation, and in some cases, it might need major surgical intervention. Hospital cost remains the highest cost component for the management of diabetic foot ulceration (DFU). Improvement of the preventive measures and patient management will result in a reduction of total healthcare costs of the related disease. The second leading component of cost is the pharmacy cost. Among these costs, antithrombotic drugs have the largest share. Increased use of generic antithrombotic drugs may be a powerful factor for reducing this cost.

Harrington *et al*[65] reported the average ulcer-related cost per year to be US$3609. Our study had 444 patients with DFU, which contributed the average ulcer-related cost per year to be US$ 3956. Stockl *et al*[66] found the average ulcer episode cost as US$13 179. In our study, the total ulcer episode cost for Qatar was US$5 851 476. Barceló *et al*[67] estimated the cost of permanent disability caused by DM. Similarly, we have attempted to assess the cost of disability using the formulae, 'The estimated cost of permanent disability=number of productive years lost to disability×the per capita gross domestic product (GDP)'. According to the GDP, Qatar comes under the high-income group with a per capita indirect cost of US$7959 for DM. Based on this, total per capita indirect cost of DM was US$44 196 327 between the year 2000 and 2014 in our study.

An earlier study from the United Arab Emirates[25] reported the annual mean treatment cost to be US$5645, which is comparatively higher than the estimated cost per patient per year US$3990 in the present study.

According to the WHO Qatar report 2016, around 38 000 individuals are diagnosed with DM, which is predicted to increase to 88 000 by 2030.[33]

Appropriate and efficient treatment of DM could significantly prevent or reduce vascular complications. Therefore, prevention of complication related to DFU is considered as the most effective means of healthcare cost reduction.

Another alternative to minimise the cost is delaying the complication as long as possible. For prevention of DFU, it is useful to train the high-risk patients and to spread awareness among patients with diabetes which have implications for cost savings.[68] The present study revealed a high cost of amputation and prosthesis. Findings of our analysis have implications to inform healthcare policy makers about the financial burden of amputations and urge the need for effective planning to improve outcomes of DM in Qatar.

A major limiting factor of the present study is the retrospective nature; therefore, the collected data might have missing information about the exact duration of diabetes. We might have underestimated the total costs as we mainly focused on the direct medical costs and cost of therapeutic interventions but did not include, payments incurred by patient, out-of-pocket costs, direct non-medical costs or other indirect costs.

We could not account pharmacy-related costs separately. The laboratory and radiological investigations, medical supplies and medications that were directly used during the course of treatment, and non-medical direct expenses were not considered in cost evaluation due to lack of sufficient data. In addition, it is imperative to know the indirect costs associated with work loss hours and residual disability. This study did not account for the indefinite costs involving pain, distress, depression, suffering and stress caused by amputation. Also the indirect costs of amputation from the societal perspective resulted in disabilities, lost productivity on the part of the patient, or premature mortality were not taken into consideration. This cost analysis study has other limitations such as lack of information about the cost of outpatient care and use of resource for chronic diseases, like hospital or home-based rehabilitation after amputation or other diabetic complications. We attempted to remove

Table 7 Prevalence of diabetes and diabetic foot complications in the Arab population

Country	WHO estimates on prevalence of diabetes[33] 2000	2030	Prevalence of diabetes mellitus	Prevalence of diabetic foot complications
Tunisia[34]	166 000	388 000	9.9% (9.5% in men vs 10.1% in female) It doubled in 15-year period	Data not available
Morocco[35]	427 000	1 138 000	6.6%	Data not available
Algeria[36–38]	Data not available	Data not available	10.6% (10.8% male vs 10.5% female)	Diabetic foot ulcer 11.9%, Neuropathy 84.85% & Peripheral arteriopathy 78.78%
Mauritania[39]	Data not available	Data not available	1.88% (1.3% males vs 2.29% female)	Data not available
Libya[40]	88 000	245 000	Data not available	Peripheral arteriopathy 60% & Neuropathy 40%
Sudan[41–43]	447 000	1 277 000	8.3% (9.9% male vs 7.5% female)	Neuropathy 37% & PVD10%
Egypt[44 45]	2 623 000	6 726 000	2.4% rural area & 8.4% in low socioeconomic class & 10% in high socioeconomic class	Foot ulcer 1% & Diabetic neuropathy 22%
Somalia[46]	97 000	331 000	2.3%	Data not available
Djibouti[47]	7000	9000	4.1%	Data not available
Yemen[48]	327 000	1 286 000	4.6% (7.4% male vs 2% female)	Data not available
Oman[49]	113 000	343 000	16.1%	Data not available
United Arab Emirates[50]	350 000	684 000	DM 29.2%, prediabetes 24.2%	Neuropathy 34.7% & PVD 11.1%
Qatar[27]	38 000	88 000	DM 16.7%, prediabetes 13.8%	Data not available
Bahrain[51 52]	37 000	99 000	DM 25.5%, prediabetes 14.7%	Neuropathy 36.6% PVD 11.8% Foot ulcer 5.9%
Kuwait[53]	104 000	319 000	12.8%	Data not available
Iraq[54 55]	668 000	2 009 000	21.4%	Diabetic foot 2.3%, Neuropathy 13%, Amputation 0.7% & PVD 0.2%
Syria[56]	627 000	2 313 000	15.6%	Data not available
Lebanon[57 58]	146 000	378 000	11.3%	PVD 18.3%
Jordan[59 60]	195 000	680 000	17.1%	Diabetic foot ulcer 5%, Neuropathy 19% & Amputation 5%
Saudi Arabia[61–63]	890 000	2 523 000	23.7%	Peripheral neuropathy 13.7%–35.9%, Diabetic foot 4.3% & Amputation 1.9%
Palestine[64 65]	Data not available	Data not available	9.6%	Data not available

PVD, peripheral vascular disease.

uncertainty as much as possible by getting good quality data, to obtain a more accurate and standardised cost estimates from the hospital finance accounting. This study has a good external validly of results because all the amputation cases were managed in our national centre.

CONCLUSIONS

The economic burden associated with upper and lower extremity amputation-related hospitalisations is considerable. DM, advanced age and sociodemographic factors influence the incidence of amputation and its associated healthcare cost in Qatar.

The findings of this study will help to showcase the economic burden of amputation, which will be the basis for better management to reduce healthcare costs. There is an urgent need for effective standardised institutional screening protocol for minor and major extremity amputations among high-risk populations. Particularly, the effective approach to manage high-risk patients with diabetes includes an extensive patient education, early assessment and aggressive treatment by a multidisciplinary team. Furthermore, effective interventions may curb the otherwise impending clinical and economic burden of amputation in population with high prevalence of risk factors.

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REFERENCES

1. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, *et al*. Estimating the prevalence of limb loss in the United States: 2005 to 2050. *Arch Phys Med Rehabil* 2008;89:422–9.
2. World Health Organization (WHO). Diabetes mellitus. 2017. http://www.who.int/mediacentre/factsheets/fs138/en/ (Accessed 15 Aug 2017).
3. Hoffstad O, Mitra N, Walsh J, *et al*. Diabetes, lower-extremity amputation, and death. *Diabetes Care* 2015;38:1852–7.
4. Trautner C, Haastert B, Spraul M, *et al*. Unchanged incidence of lower-limb amputations in a German City, 1990-1998. *Diabetes Care* 2001;24:855–9.
5. Almaraz MC, González-Romero S, Bravo M, *et al*. Incidence of lower limb amputations in individuals with and without diabetes mellitus in Andalusia (Spain) from 1998 to 2006. *Diabetes Res Clin Pract* 2012;95:399–405.
6. Narres M, Kvitkina T, Claessen H, *et al*. Incidence of lower extremity amputations in the diabetic compared with the non-diabetic population: A systematic review. *PLoS One* 2017;12:e0182081.
7. Larsson J, Apelqvist J, Agardh CD, *et al*. Decreasing incidence of major amputation in diabetic patients: a consequence of a multidisciplinary foot care team approach? *Diabet Med* 1995;12:770–6.
8. Lavery LA, Ashry HR, van Houtum W, *et al*. Variation in the incidence and proportion of diabetes-related amputations in minorities. *Diabetes Care* 1996;19:48–52.
9. Icks A, Haastert B, Trautner C, *et al*. Incidence of lower-limb amputations in the diabetic compared to the non-diabetic population. findings from nationwide insurance data, Germany, 2005-2007. *Exp Clin Endocrinol Diabetes* 2009;117:500–4.
10. MacKenzie EJ, Bosse MJ, Kellam JF, *et al*. Early predictors of long-term work disability after major limb trauma. *J Trauma* 2006;61:688–94.
11. Busse JW, Jacobs CL, Swiontkowski MF, *et al*. Complex limb salvage or early amputation for severe lower-limb injury: a meta-analysis of observational studies. *J Orthop Trauma* 2007;21:70–6.
12. Langer V. Management of major limb injuries. *ScientificWorldJournal* 2014;2014:1–13.
13. Hertel R, Strebel N, Ganz R. Amputation versus reconstruction in traumatic defects of the leg: outcome and costs. *J Orthop Trauma* 1996;10:223–9.
14. Gil J, Schiff AP, Pinzur MS. Cost comparison: limb salvage versus amputation in diabetic patients with charcot foot. *Foot Ankle Int* 2013;34:1097–9.
15. Chung KC, Saddawi-Konefka D, Haase SC, *et al*. A cost-utility analysis of amputation versus salvage for Gustilo type IIIB and IIIC open tibial fractures. *Plast Reconstr Surg* 2009;124:1965–73.
16. MacKenzie EJ, Jones AS, Bosse MJ, *et al*. Health-care costs associated with amputation or reconstruction of a limb-threatening injury. *J Bone Joint Surg Am* 2007;89:1685–92.
17. Mohamed H. Diabetic foot in Qatar: A Primary Care Perspective. Qatar Foundation Annual Research Conference Proceedings:HBPP1084. 2016. http://www.qscience.com/doi/pdf/ (Accessed 15 Aug 2017).
18. Kobelt G. Kobelt G, ed. *Forms of Health Economic Evaluation. Health economics: an introduction to economic evaluation*. 3rd edn. London: Office of Health Economics, 2013:12–31.
19. Rice DP. Cost-of-illness studies: fact or fiction? *Lancet* 1994;344:1519–20.
20. Rice DP. Cost of illness studies: what is good about them? *Inj Prev* 2000;6:177–9.
21. Hussain MA, Al-Omran M, Mamdani M, *et al*. Efficacy of a Guideline-Recommended Risk-Reduction Program to Improve Cardiovascular and Limb Outcomes in Patients With Peripheral Arterial Disease. *JAMA Surg* 2016;151:742–50.
22. Costa RHR, Cardoso NA, Procópio RJ, *et al*. Diabetic foot ulcer carries high amputation and mortality rates, particularly in the presence of advanced age, peripheral artery disease and anemia. *Diabetes Metab Syndr* 2017;11(Suppl 2):S583–7.
23. Lefebvre KM, Chevan J. Sex disparities in level of amputation. *Arch Phys Med Rehabil* 2011;92:118–24.
24. Li R, Bilik D, Brown MB, *et al*. Medical costs associated with type 2 diabetes complications and comorbidities. *Am J Manag Care* 2013;19:421–30.
25. Al-Maskari F, El-Sadig M, Nagelkerke N. Assessment of the direct medical costs of diabetes mellitus and its complications in the United Arab Emirates. *BMC Public Health* 2010;10:679.
26. Moxey PW, Gogalniceanu P, Hinchliffe RJ, *et al*. Lower extremity amputations--a review of global variability in incidence. *Diabet Med* 2011;28:1144–53.
27. Bener A, Zirie M, Janahi IM, *et al*. Prevalence of diagnosed and undiagnosed diabetes mellitus and its risk factors in a population-based study of Qatar. *Diabetes Res Clin Pract* 2009;84:99–106.
28. Brandle M, Zhou H, Smith BR, *et al*. The direct medical cost of type 2 diabetes. *Diabetes Care* 2003;26:2300–4.
29. Margolis DJ, Malay DS, Hoffstad OJ, *et al*. *Economic burden of diabetic foot ulcers and amputations*. Washington (DC): Agency for Healthcare Research and Quality, 2011.
30. Rinkel WD, Luiten J, van Dongen J, *et al*. In-hospital costs of diabetic foot disease treated by a multidisciplinary foot team. *Diabetes Res Clin Pract* 2017;132:68–78.
31. Mundell B, Maradit Kremers H, Visscher S, *et al*. Direct medical costs of accidental falls for adults with transfemoral amputations. *Prosthet Orthot Int* 2017;41:564–70.
32. Franklin H, Rajan M, Tseng CL, *et al*. Cost of lower-limb amputation in U.S. veterans with diabetes using health services data in fiscal years 2004 and 2010. *J Rehabil Res Dev* 2014;51:1325–30.
33. WHO. Country and regional data on diabetes. 2017. http://www.who.int/diabetes/facts/world_figures/en/index2.html (Accessed 15 Aug 2017).
34. Bouguerra R, Alberti H, Salem LB, *et al*. The global diabetes pandemic: the Tunisian experience. *Eur J Clin Nutr* 2007;61:160–5.
35. Tazi MA, Abir-Khalil S, Chaouki N, *et al*. Prevalence of the main cardiovascular risk factors in Morocco: results of a National Survey, 2000. *J Hypertens* 2003;21:897–903.
36. Biad A, Makhlouf L, Atif A, *et al*. The prevalence of diabetes and hypertension in East of Algiers. *J Hypertension* 2010;28:318–9.
37. Richard J-L. Le pied diabétique: fréquence, coût dépistage et prévention. *J Plaies Cicatrisations* 1997;7:127–31.
38. Benotmane A, Mohammedi F, Ayad F, *et al*. Diabetic foot lesions: etiologic and prognostic factors. *Diabetes Metab* 2000;26:113–7.
39. Ducorps M, Baleynaud S, Mayaudon H, *et al*. A prevalence survey of diabetes in Mauritania. *Diabetes Care* 1996;19:761–3.
40. Erokhsi A, Ahmed S, Aribi N, *et al*. Diabetic foot lesions in Lybian population. *Jamahiria medical journal* 2004;9:262–7.
41. Elbagir MN, Eltom MA, Elmahadi EM, *et al*. A high prevalence of diabetes mellitus and impaired glucose tolerance in the Danagla community in northern Sudan. *Diabet Med* 1998;15:164–9.
42. Elbagir MN, Eltom MA, Elmahadi EM, *et al*. A population-based study of the prevalence of diabetes and impaired glucose tolerance in adults in northern Sudan. *Diabetes Care* 1996;19:1126–8.
43. Elbagir MN, Eltom MA, Mahadi EO, Elmahadi EM, *et al*. Pattern of long-term complications in Sudanese insulin-treated diabetic patients. *Diabetes Res Clin Pract* 1995;30:59–67.
44. Wiliam HH, Ronald EA, Mohmmad AA, *et al*. Diabetes mellitus in Egypt: risk factors, prevalence and future burden. *East Mediterr Health J* 1997;3:144–8.
45. Herman WH, Aubert RE, Engelgau MM, *et al*. Diabetes mellitus in Egypt: glycaemic control and microvascular and neuropathic complications. *Diabet Med* 1998;15:1045–51.
46. International Diabetes Federation (IDF). *Diabetes Atlas*. 3rd edn, 2006.
47. Wild S, Roglic G, Green A, *et al*. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004;27:1047–53.
48. Al-Habori M, Al-Mamari M, Al-Meeri A. Type II Diabetes Mellitus and impaired glucose tolerance in Yemen: prevalence, associated metabolic changes and risk factors. *Diabetes Res Clin Pract* 2004;65:275–81.
49. Al-Lawati JA, Al Riyami AM, Mohammed AJ, *et al*. Increasing prevalence of diabetes mellitus in Oman. *Diabet Med* 2002;19:954–7.

50. Saadi H, Carruthers SG, Nagelkerke N, *et al*. Prevalence of diabetes mellitus and its complications in a population-based sample in Al Ain, United Arab Emirates. *Diabetes Res Clin Pract* 2007;78:369–77.
51. Alzurba FI, Al Garf A. Prevalence of diabetes mellitus among among Bahrainis attending primary health care centers. *East Mediterr Health J* 1996;2:274–82.
52. Al-Mahroos F, Al-Roomi K. Diabetic neuropathy, foot ulceration, peripheral vascular disease and potential risk factors among patients with diabetes in Bahrain: a nationwide primary care diabetes clinic-based study. *Ann Saudi Med* 2007;27:25–31.
53. Alnesf Y, Kamel MI ES. *A survey of risk factors for chronic non communicable disease*: Ministry of health Kuwait, 2008.
54. Mansour AA, Wanoose HL, Hani I, *et al*. Diabetes screening in Basrah, Iraq: a population-based cross-sectional study. *Diabetes Res Clin Pract* 2008;79:147–50.
55. Abbas AM. Chronic complications of diabetes in Iraq: experience from southern Iraq. *Clin Med Insights Endocrinol Diabetes* 2009:1–9.
56. Albache N, Al Ali R, Rastam S, *et al*. Epidemiology of Type 2 diabetes mellitus in Aleppo, Syria. *J Diabetes* 2010;2:85–91.
57. Hirbli KI, Jambeine MA, Slim HB, *et al*. Prevalence of diabetes in greater Beirut. *Diabetes Care* 2005;28:1262.
58. Taleb N, Salti H, Al-Mokaddam M, *et al*. Vascular complications of diabetes in Lebanon: experience at the American University of Beirut. *Br J Diabetes Vasc Dis* 2008;8:80–3.
59. Ajlouni K, Khader YS, Batieha A, *et al*. An increase in prevalence of diabetes mellitus in Jordan over 10 years. *J Diabetes Complications* 2008;22:317–24.
60. Jbour AS, Jarrah NS, Radaideh AM, *et al*. Prevalence and predictors of diabetic foot syndrome in type 2 diabetes mellitus in Jordan. *Saudi Med J* 2003;24:761–4.
61. Alnozha MM, Almaatouq MA, Almazrou YY, *et al*. Diabetes in Saudi Arabia. *Saudi Med J* 2004;25:1603–10.
62. Famuyiwa OO, Sulimani RA, Laajam MA, *et al*. Diabetes mellitus in Saudi Arabia: the clinical pattern and complications in 1,000 patients. *Ann Saudi Med* 1992;12:140–51.
63. Alwakeel JS, Sulimani R, Al-Asaad H, *et al*. Diabetes complications in 1952 type 2 diabetes mellitus patients managed in a single institution in Saudi Arabia. *Ann Saudi Med* 2008;28:260–6.
64. Husseini A, Abdul-Rahim H, Awartani F, *et al*. Prevalence of diabetes mellitus and impaired glucose tolerance in a rural Palestinian population. *East Mediterr Health J* 2000;6(5-6):1039–45.
65. Harrington C, Zagari MJ, Corea J, *et al*. A cost analysis of diabetic lower-extremity ulcers. *Diabetes Care* 2000;23:1333–8.
66. Stockl K, Vanderplas A, Tafesse E, *et al*. Costs of lower-extremity ulcers among patients with diabetes. *Diabetes Care* 2004;27:2129–34.
67. Barceló A, Aedo C, Rajpathak S, *et al*. The cost of diabetes in Latin America and the Caribbean. *Bull World Health Organ* 2003;81:19–27.
68. Oksuz E, Malhan S, Sonmez B, *et al*. Cost of illness among patients with diabetic foot ulcer in Turkey. *World J Diabetes* 2016;7:462–9.