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Original Article

Cost Estimation of Detection of Peripheral Arterial Disease by Pulse Oximeter among Diabetic Patients and Assessing its Feasibility at Family Health Centers in Alexandria

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Abstract

Background: Peripheral arterial disease (PAD) is more common in diabetic patients as compared to non-diabetic people, with a high risk of lower limb ischemia, ulcer and amputation. Pulse oximetry is a simple technique that can be used to estimate foot arterial oxygen saturation for early PAD detection in diabetic patients.
Objective(s): The study aimed to estimate the cost of detection of PAD by pulse oximeter (PO) among diabetic patients as well as assess its feasibility at family health centers/units (FHC/Us) in Alexandria.
Methods: A mixed cost estimation (quantitative) – feasibility (qualitative) study was conducted in Alexandria health directorate and eight FHC/Us in Alexandria. Key figures at Alexandria health directorate and FHC/Us were interviewed to assess the cost and feasibility of introducing PO for early PAD detection in diabetic patients at the health facilities.
Results: The cost of using PO at FHC/Us for PAD detection in one diabetic patient was 185.9 EGP (Egyptian Pound) for a positive PAD in one foot after confirming the diagnosis with doppler ultrasonography at secondary healthcare facilities. Pulse oximeter was considered a simple, easy screening tool that can have a positive impact on primary health care (PHC) diabetic patients.
Conclusion: The cost of PAD detection in one foot is considered very low and relatively affordable in relation to the cost of the consequences of PAD progression in diabetic patients. Integration of PO in PHC requires some interventions such as staff training and working environment preparedness.

Keywords: diabetes mellitus; cost estimation; family medicine; feasibility; peripheral arterial disease; pulse oximeter

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INTRODUCTION

Peripheral arterial disease (PAD) is a progressive disease marked by blockage and/or narrowing of arteries of medium and large size, excluding arteries that supply the brain and the heart.[1]

According to a systematic review comparing PAD in people with and without diabetes mellitus (DM), those with DM had PAD ranging from 20% to 50%, whereas people without DM had PAD ranging from 10% to 26%.[2] According to some studies conducted in Egypt, the prevalence of PAD in diabetic patients varies, ranging from 1.6% to 11%.[3, 4] According to another study, 43.9% of Egyptian patients with diabetic foot ulcers had PAD.[5]

The PAD has an association with an increased probability of lower limb ischemic ulceration, gangrene, and amputation. It is additionally a risk factor for thrombosis in the vasculature of the heart, brain, and kidneys. As a result, individuals with PAD are at a higher risk of myocardial infarction, stroke, and mortality.[6]

Pulse oximetry is a non-invasive method of measuring the saturation of oxygen. As an easy, non-invasive method of estimating arterial oxygenation, Pulse oximeter (PO) can be used in a wide range of healthcare settings, such as outpatient and inpatient settings, and for particular diagnostic purposes.[7]

Several studies have shown that a hand-held PO has a high level of sensitivity and specificity in

identifying asymptomatic PAD in DM patients, while doppler, duplex ultrasonography, or computed tomographic angiography is used as the reference standard test. Sensitivity had values of 74.1%, 76.7%, and 77% up to 87.06%, while specificity varied from 85.3%, 87.8%, and 95.7% to 97%.[8-11]

Cost (commonly called opportunity cost) is economically defined as 'the value of opportunity forgone, strictly the best opportunity forgone, as a result of engaging resources in an activity.'[12]

Micro-costing is a method of estimating costs that apply detailed resource utilized and cost per unit data.[13] It has proven to be especially helpful for evaluating the costs of novel techniques, techniques with great service provider variation, and the actual costs to the community and the health care system.[14]

Micro-costing is a bottom-up technique that requires straight-forward, thorough tracking of the resources utilized at each step of the care of each patient. It allows for the assessment of consumed resources at the individual level, which can then be utilized to determine the average cost of the procedure under evaluation. It increases cost-estimating precision and represents real resources by gathering thorough data on resources used and their unit costs.[15, 16] The analytical perspective of the economic assessment should be determined, either a society or health care sector perspective.[17]

Feasibility is defined as 'the quality of being possible and likely to be achieved'.[18] While, qualitative research is defined as 'an umbrella term covering an array of interpretative techniques which seek to describe, decode, translate and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world'.[19] Qualitative research is useful in addressing the feasibility of certain intervention before proceeding to its full application.[20]

Primary health care (PHC) is the best healthcare level to prevent diabetic foot disease and PHC professionals have a crucial role in foot evaluations.[21] The current study aimed at estimating the cost of detection of PAD by PO among diabetic patients and assessing its feasibility at family health centers/units (FHC/Us) in Alexandria.

METHODS

A mixed cost estimation (quantitative) – feasibility (qualitative) study design was conducted in Alexandria health directorate and eight FHC/Us selected based on the largest catchment areas; distributed in four randomly selected health districts in Alexandria Governorate.

The study targeted:

Key figures at Alexandria health directorate and FHC/Us to assess cost and feasibility of introducing pulse oximeter use at the FHC/Us.

All key figures related to the management of rural and urban PHC at Alexandria health directorate were included in the study (one Head and six assistants, while one refused). All 8 managers of FHC/Us were also included in the study. A total of 15 key figures were included and reaching saturation of key themes and preliminary analysis indicated no new data emerging.

Data collection was done through the following:

A semi-structured interview questionnaire for key figures at Alexandria health directorate and FHC/Us was designed based on literature review to estimate the cost of pulse oximeter use and its feasibility.[17, 22-24] Direct cost estimation was calculated from the healthcare perspective.

The questionnaire was divided into two parts:

1. Part 1 (quantitative part): related to PO cost estimation which included:

a) The cost of PO use at FHC/Us: this included the cost of the examination ticket at FHC/Us, the monthly salary according to family physician's (FP) financial degree, and FP's working hours per month.

b) The cost of positive PAD patient's referral: this included the cost of the examination ticket at governmental hospital outpatient clinic, the cost of doppler ultrasonography, the monthly salary according to vascular surgeon's financial degree, and vascular surgeon's working hours per month.

The cost of FPs labor time per pulse oximeter use for one patient was calculated as follows: the average number of minutes per patient X the average labor cost per minute.

- To calculate average number of minutes per patient: the researcher used a stopwatch to estimate the time needed for examining 250 diabetic cases with PO by herself and getting the mean time in minutes for one patient. Examination time included explanation of the process to the patient, examination by PO and reporting results to the patient.
- The labor cost of FPs (based on the job financial degree), was obtained by getting the monthly salary then the average labor cost per minute was calculated (6 workdays per week, 6 hours per day).

While, the cost of vascular surgeon labor time per one

patient was calculated as follows: the average number of minutes per patient X the average labor cost per minute.

- The average number of minutes per patient was obtained by getting the average number of patients per shift from a record at one governmental outpatient vascular clinic.
- The labor cost of vascular surgery physicians (based on the job financial degree), was obtained by getting the monthly salary then the average labor cost per minute was calculated (for residents and specialists 36 working hours per week, and for consultants 24 working hours per week were considered).

In addition, the following costs were added to total device use cost:

- Pulse oximeter purchase price was estimated in the United States dollar (USD) value of year 2024.
- Assuming that the PO depreciation period is eight years and the cost of yearly maintenance service was 5% of the device price[25], *the device cost per case* was calculated by summing up the device purchase price and the maintenance cost over 8 years, then dividing the result by the average number of expected diabetic patients at one clinic for 8 years[b,c].

[b] The average number of diabetic patients per day at one family medicine clinic was obtained from clinic records. (= 10 patients)

[c] Working days per year was calculated by subtracting official holidays and Fridays from 365 days. (= 295 working days)

2. Part 2 (qualitative part): related to the feasibility of PO use, the following questions were asked:

1. Do you think a pulse oximeter is needed in FHC/Us for PAD screening in diabetic patients? Why?
2. In case it will be introduced to FHC/Us, what suggestions do you have to facilitate the incorporation of PO in FHC/Us?
3. In your opinion, what are the possible barriers that may be encountered for its incorporation in FHC/Us?
4. How can these barrier(s) be overcome?
5. What effect, if any, do you think the device may have on diabetic patients of FHC/Us?
6. Is there anything more you would like to add?

Interviews were done by the study's first author in Alexandria health directorate and FHC/Us. They began with a question about how family physicians currently manage patients with diabetic foot disease. After rapport was established with the participants, the interview then moved towards open-ended questions exploring the key constructs of the interview guide. The use of silent probes, elaboration and restatement of questions was used to get more in-depth responses.

The mean duration of interview was around 3 minutes. Interviews were recorded on a digital audio recorder, then transcribed by intelligent verbatim into document files and revised by two of the researchers for any mistakes or incompleteness, as interviews were conducted in Arabic, the transcribed interview files were translated to English.

Data were collected during the period of February to April 2024.

Data analysis:

The qualitative data collected from key figures about the feasibility of PO was analyzed using thematic analysis guided by Braun and Clarke's methodology. A deductive process was applied as the analysis themes were predetermined.[26] The following six steps were applied during analysis:

1. Familiarization with the data: by the transcription of data, then viewing the data and cross-checking the transcripts against the voice recordings to ensure accuracy.
2. Developing initial codes: by manually coding relevant data and linking them to data extracts that illustrate each code.
3. Identifying themes: by collecting all relevant codes to the predetermined five themes and creating a mind map of the analysis (figure 1).
4. Reviewing of the themes: themes were reviewed to ensure internal homogeneity, where all data within each theme formed a coherent pattern. Simultaneously, themes were checked for external heterogeneity to ensure that each theme was distinct and did not overlap meaningfully with others. Some initial codes were reclassified, refined into subthemes, or excluded when lacking thematic fit.
5. Naming and defining the themes: by creating clarified definitions and titles for each theme.
6. Generating the results: by offering a concise, consistent, and logical analysis, as well as vibrant excerpts of data extractions.

Ethical Considerations:

- The study was approved by the Research Ethics Committee of the High Institute of Public Health and the Ministry of Health (Institutional review board 0000687).
- An informed verbal consent was taken from study participants to record the interviews after explanation of the purpose and benefits of the research.
- Anonymity and confidentiality were assured and maintained.
- The researcher complied with the International Guidelines for Research Ethics.
- There was no conflict of interest.

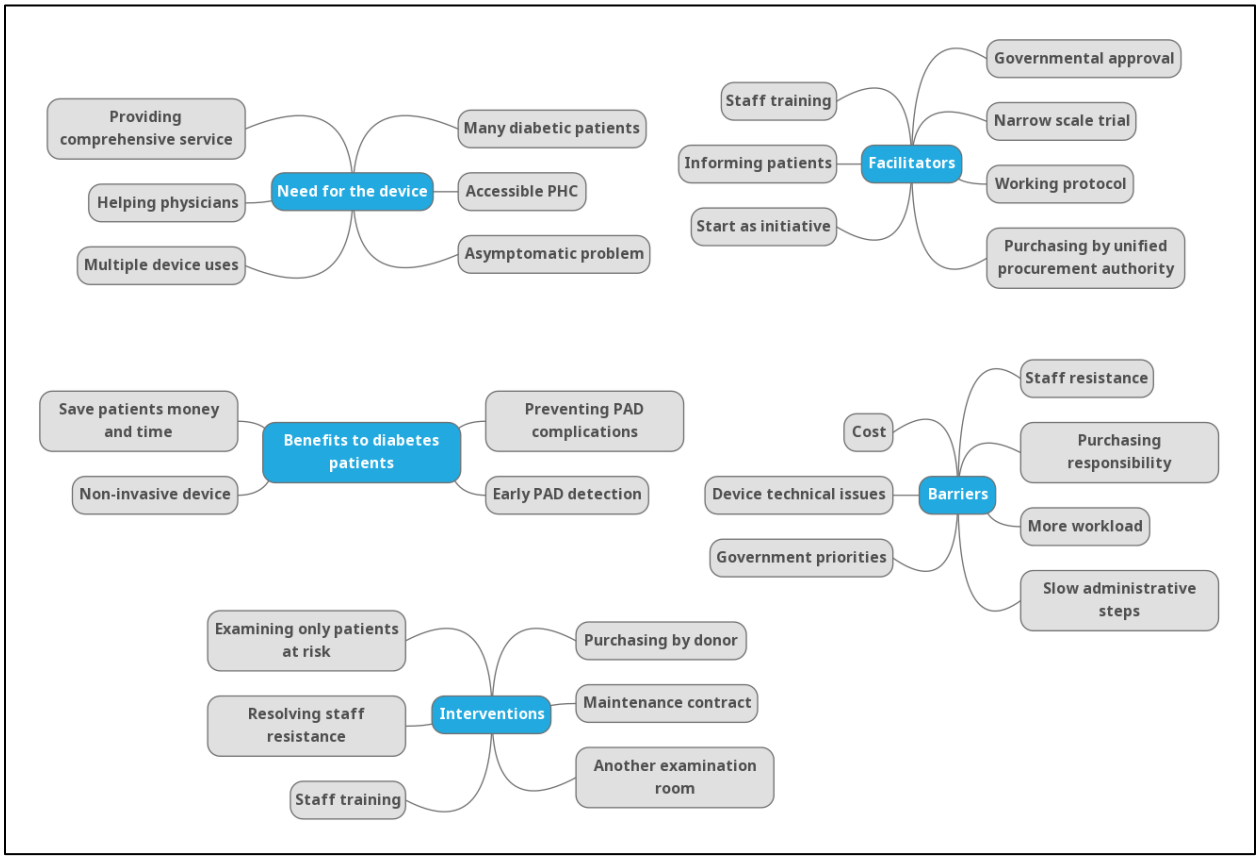

Figure 1: Initial mind map of the generated codes for the five predetermined themes

RESULTS

The costs were divided into three main categories (table 1): (1) the device purchase price and maintenance costs; (2) the cost of PO use at FHC/Us; and (3) the referral cost of a positive PAD case.

Regarding the first category, the price of PO in 2021 was equal to 140 USD. To calculate the PO purchase cost in EGP (Egyptian pound) in 2024, the device price in dollars was converted to its equivalent in EGP, which equals 6700 EGP, according to the dollar price at the time of calculation.

Assuming the annual maintenance cost equals 5% of the purchase price, it was calculated as follows: 6700 x 5/100 = 335 EGP. Also, the depreciation period of the PO is 8 years, so the total maintenance cost over 8 years equals 335 x 8 = 2680 EGP. To sum up, the total device cost for 8 years equals 9380 EGP.

As regards the second category, the device use cost per one diabetic case was calculated by dividing the PO cost in 8 years by the average number of expected diabetic patients attending one clinic (10 patients) in 8 years (295 annual working days x 8).

The PO labor cost of FPs was calculated by multiplying the cost of FP's labor minute x PO examination time per case. The cost of FP's labor minute was calculated by dividing the average monthly salary of FPs (based on the job financial degree) by labor minutes per month, which equals 7862.5 EGP/8640 minutes = 0.91 EGP/minute. Then, multiplying the latter by PO examination time per case (3.4 minutes), which equals 0.91 x 3.4 = 3.1 EGP.

By summing up, the cost of PO use at FHC/Us includes the cost of examination ticket, the device use cost per case, and PO labor cost per case, which equals 8.5 EGP.

Concerning the third category, the labor cost of a vascular surgeon per patient was calculated by multiplying the cost of a vascular surgeon labor minute x the average number of minutes per patient. The cost of vascular surgeon labor minute was calculated by dividing the average monthly salary of vascular surgeon (based on the job financial degree) by average labor minutes per month[a], which equals 7862.5 EGP/7200 minutes = 1.1 EGP/minute. Then, multiplying the latter by vascular examination time per patient (6.7 minutes), which equals 1.1 x 6.7 = 7.4 EGP.

By summing up, the cost to confirm PAD diagnosis for the possible positive case includes the cost of examination ticket, vascular surgeon labor cost per case at a governmental hospital outpatient clinic, and cost of doppler ultrasonography at a governmental hospital, which equals 177.4 EGP. To sum up, the cost of detection of PAD in one feet of a diabetic patient equals 8.5 EGP + 177.4 EGP = 185.9 EGP.

[a] The number of labor minutes per month of a vascular surgeon is 8640 or 5760 minutes (resident and specialist: 36 hours per week, consultant: 24 hours per week).

Table (1): **Cost estimation of Pulse oximeter use for detection of peripheral arterial disease in one foot of a diabetic patient attending family health facilities in Alexandria in 2024**

Cost items		Cost by Egyptian pound (2024)	
The PO* cost			
Purchase price		140 USD ≃ 6700 EGP	
Maintenance cost (8 years)		335 EGP x 8 = 2680 EGP	
Total		9380 EGP	
Cost at family health facilities			
		PO positive case	**PO negative case**
Cost of the examination ticket at family health facilities		▪ 5 EGP	▪ 5 EGP
The device use cost per case [a]		•0.41 EGP	• 0.41 EGP
	FPs' financial degree and monthly salary		
PO labor cost of FPs per case [b]	▪ 3rd degree: 7050 EGP ▪ 2nd degree: 7800 EGP ▪ 1st degree: 8100 EGP ▪ Chief doctor: 8500 EGP	Mean = 3.1 EGP	Mean = 3.1 EGP
Total		8.5 EGP	
Referral cost			
Cost of the examination ticket at governmental hospital outpatient clinic		▪ 10 EGP	
Cost of the doppler ultrasonography at governmental hospital		▪ 160 EGP per leg	
	Vascular surgeon's financial degree and monthly salary		
Labor cost of vascular surgeon per patient	▪ 3rd degree: 7050 EGP ▪ 2nd degree: 7800 EGP ▪ 1st degree: 8100 EGP ▪ Chief doctor: 8500 EGP	Mean = 7.4 EGP	
Total		177.4 EGP	
Total cost per patient		**185.9 EGP**	**8.5 EGP**

* PO: pulse oximeter

[a]: the average number of expected diabetic patients attending one clinic in 8 years, equals 10 patients x 295 annual working days x 8 years = 23.600 patients. So, the device use cost per case equals 9380/23.600 = 0.41 EGP.

[b]: the PO labor cost of FPs equals the cost of FP's labor minute x PO examination time per case which is 3.4 minutes.

Regarding PO feasibility (table 2), the participants' responses yielded 139 relevant data excerpts that were classified into 29 codes and 2 subthemes. These were in turn categorized into the 5 main preexisting themes. The 5 main themes are: (1) the need for the PO; (2) facilitators for integration; (3) barriers against integration; (4) interventions to overcome barriers; and (5) perceived benefits to diabetic patients.

Themes:

1: The need for the PO

'The need for the PO' indicates causes that gave rise to demanding the presence of the PO in FHC/Us. While all agreed about the need for the device, the most reported reason for needing it was the early detection of PAD. It was thought as an important step to prevent diabetic foot complications. Two of the replies were: "*Cases will be discovered early and dealt with before we get into complications.*" "*With early detection, there will be better treatment and management.*"

Also, some participants talked about the high frequency of chronic patients at FHC/Us, especially DM patients, which leads to increased encounters of diabetic foot problems at health facilities. One respondent reported that *"Chronic patients and diabetic patients are too much in primary health care, and of course, the diabetic foot is seen frequently*."

PHC must be accessible to everyone, and this was one of the codes that was generated from the talks of participants. The geographical and financial accessibility of PHC to diabetic patients were seen as

one of the reasons for needing such a device. Also, the regular visits of chronic patients to PHC can help with the follow-up of diabetic foot. The following excerpts revealed that: "*Not all people have the ability to go to hospitals. The place may be far away from them. It's easier to follow up with the patient here as he already came to dispense his medications*." "*It's going to be an extra service for people; for example, they're not capable of doing it in another place at a high cost, so it's going to be a good thing, a free thing."*

Other interviewees found that the PO will help to provide comprehensive service for diabetic patients, as there are now in PHC facilities different measures to handle diabetic complications such as nutritional, psychological and cardiac assessments. Regarding diabetic foot arterial problems, the device will help with timely prevention and early treatment. It was reported that "*The problem is that we only educate patients about hygiene, which is a simple thing. But if you tell them (patients), you have a problem, and you must take this medication right now to avoid peripheral vasoconstriction. It's not just talk. I've already given him a cure before the problem occurs*."

In addition, some respondents said that The PO is an additional tool that can help physicians to evaluate diabetic foot arterial problems besides the regular manoeuvres. One of the participants commented, "*Of course, they see diabetic feet frequently, so this will be a very good thing for them to evaluate the case*."

One subtheme was developed during data analysis, as some respondents talked about the PO's advantages as a device itself. Being non-invasive and having other medical uses make the presence of the device at FHC/Us a good idea. One of the responses was "*It's also possible to use the device for other needs, not just for DM*," while another one was "*Of course, a thing like that can diagnose and is not considered an invasive technique. Any patient will benefit*."

2: Facilitators for integration

The theme 'facilitators for integration' means any factor that can make it easy for the PO to be incorporated for PAD detection, starting from the MOHP down to FHC/Us. When asked about facilitators, many respondents reflected that obtaining governmental approval is an essential step. Examples of this code include: "*In the first place, it's proposed to the ministry's primary care committee*." "*We don't work alone; it must be a central approval; no one works in such a thing without having the approval of the ministry*."

Staff training was another prominent code, which meant holding workshops so that staff could know how PO works and become able to use it correctly. One of the replies was, "*Of course, the staff who will work with it must be well trained; there must be many practical workshops for them, not only theoretical ones. This means they hold the device and try it themselves."*

For getting the device, the Egyptian authority for unified procurement (UPA) was the only way to purchase the PO by FHC/Us, in case of the device wouldn't be supplied directly by the MOHP. One respondent said that: "*I request the device on the electronic gate (of UPA), and the registered companies will see if they have the device's specifications or not. They propose and come to the center with their offer of prices*."

Some participants suggested starting using the PO on a narrow scale at first so that it could be evaluated before generalization. While one participant suggested starting at FHCs so it could be used by the specialists. The following responses were mentioned: "*If we carry it out like a pilot study, for example, on a unit at first, and we'll see the result.*" "*Even as a pilot, for example, we have 109 health units, so if we are going to apply it, we can start with one-third or half of the units*."

Inside the FHC/Us, some participants pointed out the presidential initiatives as a path of entry for the PO in daily practice, while others thought that it could be integrated within the regular clinic services for DM patients. As demonstrated in the next replies, "*It can get into an initiative, such as a presidential initiative; they supply the devices, and we do screening on a large scale.*" "*We can generalize it, either in primary care service or in a new initiative*."

While other respondents jumped to the easier answer that entails releasing a PO working protocol by the MOHP: "*It's a work protocol; they (MOHP key figures) must approve the device incorporation, and they issue its protocol."* However, one participant pointed out the importance of the presence of a referral protocol: "*It's necessary to have a referral protocol. A protocol from the center to the hospital… to the diabetic foot clinics*."

The last facilitator was reported by one participant, who drew attention to the importance of announcing to DM patients the availability of the service: "*And after that, we inform the health education department to start notifying people in the units that this service and device is present; they explain the concept itself to patients."*

3: Barriers against integration

'Barriers against integration' are defined as any factor that can hinder the incorporation of the PO for PAD detection, starting from the MOHP down to FHC/Us. The most reported obstacle was PO cost. As the dollar price is rapidly rising in short periods, this necessitates the high price of the imported devices. Also, some participants inquired about who would cover these costs. Typical responses were: "*The question is: who would provide it (PO)?*" "*This will need a budget."* "*The cost, of course; these things are*

getting more expensive." "*The inability to provide it for all units.*"

Many participants focused on the technical aspects of the PO as a device, which needs to be durable with a long-lasting battery and available maintenance service. This will help to avoid wasting money or turning the device into a stagnant one. Some examples include "*Its maintenance. Are spare parts available? Is there a manual? and if it is an old model, its spare parts won't be available now.*" "*How long is the life of the battery, and how many cases can be assessed in a day? If the battery's daily consumption is high, this would decrease its life. What's the price of the battery?*" "*Its depreciation: using the device too much can lead to quick depreciation. They (the staff) will use it for a period, and then, after it breaks down, they will have to buy it again.*"

Another evident barrier was increasing the work load on physicians at family health clinics, as assessing one DM patient takes, on average, 3.4 minutes as determined by the researcher's stopwatch. Considering the high number of DM patients and the overcrowded clinics at FHC/Us, this would cause an overburden on physicians and impede other work procedures. As illustrated in the following excerpts: "*The clinic already has a crowd and a load of examinations of other cases, files, and many other procedures."* "*It's hard to stop work for, like, three or four minutes to use it."*

Some participants talked about the current ministry's priorities and plans that could hinder the incorporation of the device: "*Maybe for them (the MOHP), there are other devices that have a higher purchasing priority.*" "*Does the ministry have alternative plans for hospitals*?!"

Also, the slow administrative procedures—either the ministry's approval of integration or the purchasing process—were mentioned as a time barrier that could delay but not hinder the device integration. "*It may take time to get the approval of the ministry of health; such things aren't done at a quick pace.*"

Regarding FHC/Us working staff, a few participants talked about possible resistance to using the device. One view drew attention to the device guardianship; staff may fear this responsibility as the device is small in size and can be easily stolen. The other view talked about the natural human's resistance to change. As shown in the following responses: "*Staff may be afraid to deal with it because it's light in weight and can be stolen.*" "*If you're going to tell them (the staff) that we're going to apply a new thing, it is normal to find resistance.*"

Confirming the PO sensitivity in detecting PAD was emphasized by a few participants, as using such a device in the early detection of PAD was a new approach to hear about. One participant said: "*They will (the MOHP) do an audit on the device and try it within a pilot study on patients with possible PAD, which will then be compared with the gold standard*."

4: Interventions to overcome barriers

The theme 'interventions to overcome barriers' indicates any possible action that could be taken to deal with the expected barriers facing PO incorporation. Concerning the expected PO cost barrier, many participants suggested purchasing the device through donations. Donors could be a financially competent person or even the public. As presented in the following responses: "*We get it in by donation, which is the most appropriate way.*", "*Maybe if we bring this up to the people, they can make donations for it.*" "*A donor donates to us.. according to what (quantity) he/she can provide.*"

Three suggestions were shared by participants to get over the barrier of 'increasing the work load on physicians. These proposed solutions were gathered under a subtheme named 'decreasing the work load on physicians'. One solution was to not use the device for all DM patients and only restrict it to patients with risk factors for PAD or its complications. One respondent said, "*The physician may have a checklist containing questions and clinical findings, and if the patient is found to be at high risk, then the assessment by PO is done.*"

The second suggestion was to assess patients in another examination room other than the family health clinic to prevent the overcrowding from getting worse and to allow the physicians to do their regular duties properly without frequent interruption. These three excerpts illustrate the suggested solution: "*Maybe we could put it in the emergency room.*", "*We could put the device in the specialist's clinic.*", "*It is possible to have a specialized clinic here, at the center (FHC), and any diabetic cases will be referred to it. A doctor or a nurse who's specialized examines the cases and sends us (FPs) back the results.*"

The last suggestion was not to restrict the PO assessment of PAD to only physicians, as the device is easy to use and the results are easy to interpret. It was suggested to be used by any trained health care professionals, such as nurses, pharmacists, and technicians. As revealed in this reply, "*It can be done, not necessary, by a physician; we can train nurses, pharmacists, and dentists. I think its (PO) maneuver is easy.*"

Regarding PO maintenance as a barrier, some participants mentioned the necessity of the presence of a maintenance contract and making sure of the availability of device spare parts. When asked about overcoming the barrier, these were some responses: "*The company must have complete spare parts and maintenance."* "*We make maintenance contracts from its first entry, and we know how to conserve it.*"

For working staff resistance, one participant suggested two solutions. The first one is to convince

the staff at the beginning of the device concept, and the second one is to keep the device in a closed cabinet. As shown in this answer, "*You must convince staff at first that this device won't cause a load on you, it is easy to use. Once you convince people with the idea at first, it is finished.*"

5: Perceived benefits to diabetic patients

'Perceived benefits to diabetic patients' indicates how participants think the PO may positively affect diabetic patients. The most dominant code was preventing PAD complications in DM patients such as amputations, handicapping, negative psychological impacts, and subsequent rehabilitation because the PO can help early identification of lower limb arterial disorders even with no evident symptoms. The following quotes confirm the code: "*It will decrease patients' morbidity and improve their lifestyle*." "*Early detection will prevent the disaster from happening when we have to do an amputation or resort to a procedure that won't please the patient.*"

Also, some participants saw that providing such a device would benefit patients attending FHC/Us as it would be a free or even in an affordable price compared to prices in private facilities. Furthermore, this will save a significant amount of time spent on patient referrals to overcrowded or distant ministry hospitals. These were two replies: "*It will save the patient's time, and a referral will be directed to the right medical path.*" "*It will prevent much suffering, as we send the patient to do investigations, then we send him to governmental hospitals, which are all crowded, so as to reach an early diagnosis of PAD.*"

Table (2): Feasibility themes and generated codes about pulse oximeter use for peripheral arterial disease detection among diabetic patients at family health facilities in Alexandria in 2024

Themes	No. of excerpts
1. The need for the PO*	
➢ ***Codes***	
▪ Early detection of PAD*	**9**
▪ Large number of diabetics attending family health facilities	**4**
▪ Primary health care is more accessible to patients	**4**
▪ To provide comprehensive service to diabetics	**2**
▪ To help physicians to evaluate diabetic foot cases	**2**
▪ ***Subtheme: device's convenience***	
▪ PO has other multiple uses	**1**
▪ PO is a non-invasive device	**1**
2. Facilitators for integration	
➢ ***Codes***	
▪ Ministry's approval is the first step	**10**
▪ Staff training	**7**
▪ Purchasing the PO through the Egyptian authority for unified procurement	**4**
▪ PO trial on narrow scale at first	
▪ Integrate the PO into an initiative or into regular primary health care service	**4**
▪ Release PO working protocol by Ministry of Health	**4**
▪ Inform patients of service availability	
	4
	1
3. Barriers against integration	
➢ ***Codes***	
▪ PO cost and purchasing responsibility	**13**
▪ PO battery, maintenance, and depreciation	**8**
▪ Increasing the work load on physicians	**7**
▪ Ministry's priorities	**5**
▪ Slow administrative steps	**3**
▪ Staff resistance	**3**
▪ Assessment of PO sensitivity	**3**
4. Interventions to overcome barriers	
➢ ***Codes***	
▪ Purchasing PO* by a donor	**9**
▪ ***Subtheme: Decreasing the workload on physicians***	
▪ Assess only patients prone to PAD*	**4**
▪ Another examination room	**4**
▪ Utilized by trained health care professionals	**3**
▪ The presence of maintenance contract	**4**
▪ Resolve staff resistance	**2**
5. Perceived benefits to diabetic patients	
➢ ***Codes***	**10**
▪ Prevent complications of PAD	**4**

*PO: pulse oximeter * PAD: peripheral arterial disease

DISCUSSION

In PHC, missing diagnosis of PAD could be a serious problem. Many people who suffer from PAD either don't exhibit any symptoms or have unusual symptoms that don't quite fit the description of claudication. PAD serves as an indicator of systemic atherosclerosis. Individuals diagnosed with PAD are at the same cardiovascular risk as those who have experienced a prior cardiac infarction.[27] The PO has shown higher sensitivity and higher or similar specificity in detecting PAD in asymptomatic diabetic patients when compared to Ankle Brachial Index.[9, 11] However, a higher sensitivity value was obtained when both techniques were combined in the diagnosis of PAD.[11]

To the best of the researcher's knowledge, this is the first study to estimate the cost of PO use in early PAD detection in diabetics. In the present study, direct costs of PO use to detect PAD in diabetic patients were estimated from the healthcare sector perspective. In terms of the device cost, the accumulated PO cost in 8 years was 9380 EGP. It is evident that the primary factor influencing the total cost is the device cost; however, the reusable probe used in the current study has contributed to notable savings in the device expenses and, consequently, a reduction in the overall cost.

An observational study in the United States of America was conducted to assess the cost of PO use in screening newborns for congenital heart diseases and found that the cost of use of a reusable probe per newborn was only 0.25 USD as compared to 21.92 USD when using disposable ones.[28]

A review that included six studies examining the cost of PO use in the newborn screening of congenital heart diseases found that cost estimates exhibit significant variation due to the types of utilized probes. Using a reusable probe has a much lower variable cost per patient than using a disposable one, yet reusable probes do require maintenance costs.[17]

The current study revealed that one case examination takes an average of 3.4 minutes, which includes explaining the process to the patient and informing them of the result. Consequently, labor expenses are relatively low and vary a little depending on the salary of the FP. However, more time would be needed if the process would include the documentation of the screening result either on paper, electronically or both. This can elongate the screening time, with subsequent increase in the physician labor cost per patient. Positive PAD cases would need further evaluation and investigation to confirm the diagnosis, with an additional cost of 177.4 EGP.

In this study, PAD was found in 0.6% of diabetic patients and the total cost of early PAD in a single foot in one patient was 185.9 EGP. This is considered a low relatively affordable cost. The cost data of the present study can be used by future researchers to assess the cost-effectiveness of this intervention.

With regard to the opinions of the Alexandria health directorate and FHC/Us key figures about the feasibility of PO use for early PAD detection in DM patients, results indicate that it was acceptable and even needed to provide comprehensive, financially affordable PHC service for the large diabetic population served through PHC.

Getting ministerial approval is seen as the key first step in bringing pulse oximeters into routine use at family health facilities. But approval alone isn’t enough—there also needs to be a clear, practical protocol that lays out how screening will be done, who will be responsible, how patients will be referred if needed, and how follow-up will be handled. Fortunately, the device is simple and easy to use, which means it wouldn’t be difficult to train a variety of healthcare staff, including nurses and family doctors, to use it confidently.

Supporting this need for a structured approach, a qualitative study exploring the barriers and facilitators to implementing a new screening tool in an emergency department found that leadership and resource availability were perceived as essential organizational prerequisites for successful integration. Participants and their managers emphasized the importance of specific conditions, including adequate staffing, designated key personnel, and strong leadership support, all of which were deemed necessary for ensuring the tool’s effective and sustainable implementation.[29]

The use of PO needs the availability of a proper clinic atmosphere that allows the patient to stay stable and the FP or the nurse to make sure of a correct, accurate reading. To obtain accurate PO readings, patient must maintain foot steadiness as any movement can result in erratic pulse wave.[30] A crowded clinic with constant movement from patients, relatives, and pharmaceutical sales representatives can interfere with a patient's ability to remain steady during an examination. In addition, the examiner must maintain focus to record the stable oxygen saturation measurement reading, which is the one that remains steady by ±1% for at least 10 seconds while exhibiting good signal strength.[31]

Releasing new policies to prevent patients overcrowding can help to properly use the device. Otherwise, the device can be used in another room with other assigned health care personnel. In our study, increasing the work load on physicians was discussed by participants as one of the barriers to use PO. Insufficient time tends to be a common barrier commonly reported as a barrier for successful

implementation of new tools in healthcare.[32, 33]

CONCLUSION AND RECOMMENDATIONS

The cost of using PO at FHC/Us for PAD detection in one diabetic patient was 8.5 EGP for a negative PAD case and 185.9 EGP for a positive PAD in one foot to confirm diagnosis by doppler ultrasonography at secondary healthcare facilities.

PO was considered a simple, easy screening tool that can have a positive impact on PHC patients; however, its integration needs interventions, such as training of physicians and nurses, ensuring suitable clinic conditions for examination, and establishing a two-way referral pathway for positive cases.

Evaluating the cost-effectiveness of PO use for early detection of PAD in diabetic patients is recommended

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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