Treatment outcomes among tuberculosis patients in Jeddah, Saudi Arabia: Results of a community mobile outreach directly observed Treatment, Short-course (DOTS) project, compared to a standard facility-based DOTS: A randomized controlled trial

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ABSTRACT

Introduction: Tuberculosis (TB) remains a global public health threat affecting people in many developing countries, including the Kingdom of Saudi Arabia. Maintaining a long-term treatment regimen has always been the cornerstone of successful treatment outcomes among tuberculosis patients. In the Jeddah region, the National Tuberculosis Control and Prevention Program is now treating TB patients by means of a community mobile outreach team approach.

The objective of this study was to compare the effectiveness of the community mobile outreach approach in improving treatment outcomes (success rate) among local tuberculosis patients with those being treated with a facility-based directly observed treatment, short-course (DOTS).

Study design: Our study consisted of a two-sample, parallel design [1:1], statistician -blind randomized control trial with 200 newly diagnosed, TB patients as subjects.

Setting/participants: The patients had all presented at the Madain Alfahd Primary Health Care Center, Jeddah. Between Nov 2017 and Nov 2018, a total of 221 TB patients were screened of whom 200 were randomly selected using randomly generated sequences.

Intervention: Patients in the intervention sample group were treated by means of mobile outreach teams with oral anti-TB treatment under the DOTS, and control group patients were given the traditional facility-based DOTS treatment according to the WHO recommendations and national guidelines.

Main outcome: The primary outcome was the level of overall treatment success rate. It was finally determined and compared in the two sample groups using chi-square analysis and relative risk assessment.

Results: In the analysis stage, 97 patients were in the intervention group, while the control group consisted of 76. The overall response rate was 86.5% (173/200). We found that the percentage of overall treatment success rate among the patients served by the mobile outreach team was 97%, compared to 76% in the non-mobile team treated patients. The relative risk of treatment success rate among the intervention group was 1.27 (95% CI = 1.13–1.43) times greater than that amongst the control group. Log-rank test (log-rank statistics = 18.91; $p < 0.001$) identified a significant difference in the default rate after six months of treatment.

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Conclusion: This study has shown that a mobile outreach DOTS approach is an effective and acceptable strategy for treating TB patients. It also provides important data on the efficacy of using mobile outreach teams to improve TB treatment outcomes in Jeddah. Our results provide evidence and highlight the positive and significant impact of mobile outreach teams in mitigating TB recurrence rates and in improving TB treatment outcomes.

Clinical Trial Registration: Clinicaltrials.gov: NCT03787914

1. Introduction

Despite improved diagnosis, treatment and prevention programs, tuberculosis (TB) remains a significant public health concern and a leading cause of mortality and morbidity worldwide, especially in developing countries [1,2]. A recently published 2018 Global Tuberculosis Report indicated that almost one-third of the world population is infected, with around 10.4 million reported cases [3,4]. Of these, around 500,000 are new cases of multi-drug resistance TB, as well as around 100,000 new cases with rifampicin-resistant TB [2–4]. It also showed that with around 1.4 million reported deaths resulting from TB, more than 95% occurred in low and middle-income countries [5,6]. These figures are probably an underestimate of the true impact of the disease since many cases are either not diagnosed or reported [2,5]. The global drop in TB incidence from 2014 to 2015 has been shown to be only 1.5% [2–4].

The literature has identified patient compliance with anti-TB drugs as a main factor for the ultimate success [3–5]. The long period of treatment necessary even after clinical recovery is the commonest cause of patient non-compliance and those lost to follow up [7]. Other reasons for not completing treatment include fear of side effects, lack of knowledge regarding the full treatment course, fear of the social stigma associated with an infectious disease like TB, and ignorance of the resultant complications like relapse, drug resistance and potentially prolonged hospitalization as a result of treatment non-compliance on the part of these patients [7,8]. Recognizing patient non-compliance and treatment drop-out as the primary obstacles to the aim of increasing cure levels worldwide, in 1993 the World Health Organization (WHO) launched a directly observed treatment, short-course (DOTS) strategy [1]. After several years of practice treating patients with different methods, the DOTS strategy has been shown to be the most effective method of dealing with the disease [1,2]. A treatment observer is assigned to each patient to ensure that the patient is taking his medicine regularly and at the prescribed intervals. This treatment observer can either be a healthcare worker, or family member or any other suitable person. Reports in the literature have shown the DOTS approach to be highly effective in reducing treatment failure rate [2,5].

The target set by the WHO was to reduce TB-related deaths by 50% by the year 2015, with a projected successful treatment rate of recovery in around 85% of patients under the DOTS strategy [3,4,9]. However, several recent reports and studies have shown a re-emergence of TB worldwide, particularly in developing countries [8]. When by 2014, it appeared that these targets could not be achieved, the WHO End TB Strategy was extended, and the targets revised to achieving a 90% reduction in deaths due to TB, together with an 80% reduction in the overall incidence rate by 2030 instead of by 2015 [2,5].

Meeting these WHO End TB Strategy milestones will require huge efforts and funding. According to 2015 WHO reports, the Kingdom of Saudi Arabia (KSA) has a low to middle Incidence of TB, with a rate of 12 per 100,000 [10]. The vast economic expansion in the Kingdom has resulted in an influx of a large number of foreign workers. The majority come from TB-endemic countries in Asia and Africa, thus presenting a potential health risk for the KSA [10,11]. They are scattered all over the country and many of them suffer from the disease. In addition to the legal migrants, a large number of illegal and consequently unregistered migrants are found in almost every province. Recent studies have shown that the majority of reported TB cases (56%) are among non-Saudi's,

who not only represent carriers of the bulk of the drug-resistant strains but are also the highest number of patients who are lost to follow up [12–14]. In addition, because the KSA is a Muslim religious centre, with Holy Mosques and the venue for the Hajj or Umrah, millions of pilgrims travel here from all over the world each year. The majority of pilgrims are also from highly TB-endemic Asian and African regions. Overcrowding, high levels of physical exertion during the pilgrimage, and the presence of all age groups amongst these pilgrims can provide optimum conditions for the transmission of many infectious diseases, TB being one of them [13–15].

The Saudi National TB Control and Prevention program (NTCPP) was initiated more than 30 years ago under the aegis of the Ministry of Health (MOH). The NTCPP adopted the WHO standard TB treatment strategy, i.e. the DOTS program, in 1999 [11,13]. Even after adopting the DOTS program, the treatment coverage of TB patients is around 87% in the country, yet the treatment success rate for new and relapsed cases is only 62% [2]. This falls below according to the current WHO TB treatment goals of 85% [3,4]. The main obstacles to the cure of TB patients in the KSA, as identified in the literature, are patient non-compliance with treatment regimens and patient interruption of medication routines [2,13,16]. Successfully curing the disease depends on the patient regularly taking the prescribed drugs, which in our region, we can never be sure of. Even if the patient is regularly visiting a clinic, health professionals and treatment observers are sometimes not too sure whether or not he/she is taking the medicines [5,17–19]. As some studies have shown, patients tend to misinform and even lie to the treatment observer [17–19]. In response to this, this year the NTCPP has introduced the new concept of community mobile outreach teams. The idea behind these mobile teams is that the anti-TB drugs are taken by the team member to the patient's doorstep and administered to the patient under his direct supervision.

This mobile outreach team approach was first introduced in the provinces of Riyadh and Jizan. As a result of the positive impact of this program on TB cure rates in these provinces, and after recommendations from the MOH in Riyadh, it was now introduced in the city of Jeddah [2]. The aim of these mobile outreach teams is to improve patient outcomes (i.e. success rate) and to decrease the patient default rate by means of the presence of mobile outreach teams in the community. Taking medicine to the patient's home and administering it to the patient in the presence of the team members not only ensures compliance but ultimately decreases the incidence of the disease. This holistic care approach for the treatment of TB patients ensures adherence to all aspects of the DOTS strategy.

The aim of our study was to evaluate the impact of the community mobile outreach teams on TB treatment outcomes by comparing treatment outcomes in those patients who were not served by mobile outreach teams in the Jeddah Region with those who were.

2. Materials & methods

2.1. Study design

Our study was based on a single centered (conducted in a Primary Health Care Center (PHCC) specified for the treatment of lung diseases including TB, i.e. Madan Alfahd) with balanced randomization [1:1], in a statistician-blind parallel-group randomized control trial conducted in Jeddah, KSA. The duration of the study was around one year, from

approval, and including data collection and report writing, and was undertaken during the year from November 1st 2017 to November 1st 2018. The study involved the treatment of TB patients according to two different management approaches and then comparing the results. TB management under the DOTS initiative was assessed and compared in the two groups; one getting medication at the place of their convenience supervised by the mobile outreach team, while the other group of patients had to go the health facility to get their medicine. Facility-based staff include doctors (pulmonologist, family medicine doctors and GPs), nurses and pharmacists, all were given routine TB management training. Moreover, a treatment observer responsible for dose administration was assigned to each facility based patient who could be either a healthcare professional or a family member/notable. In case the patient did not come on his/her scheduled appointment, a reminder SMS is sent after three days followed by phone calls after one and two weeks. If there is no response, treatment observer is contacted. After one month of failed follow-up attempts, regional coordinator is sent to the provided address.

On the other hand, mobile teams consisted of health care professionals, including nurses, and were under the supervision of doctors. The mobile teams' members were given three days of TB management training. In addition, there were frequent surprise visits by supervisors to check on the mobile outreach team service delivery. Infectious Disease Department of the Directorate of Public Health was responsible for the team's transport.

The study was approved by the Research Ethics Board of Ministry of Health and Directorate of Health Affairs Jeddah (H-02-J-002–00877). This trial was registered at the Clinical Trial Registration under Clinicaltrials.gov registration # NCT03787914.

(https://clinicaltrials.gov/ct2/show/NCT03787914)

2.2. Study population

The participants in our study were new and recently diagnosed (two months or less) TB cases (either pulmonary or extra-pulmonary). Diagnosis of active TB cases was made according to the WHO recommendations and national guidelines [2,4,13,20]. A patient presenting with a history of cough for more than two weeks along with fever or weight loss was further evaluated. Radiographic imaging, sputum smear-positive result (grade 1–4) for AFB examined using Ziehl-Neelson was then followed by culture and PCR for diagnosing pulmonary TB. Whereas, extrapulmonary TB was diagnosed by suggestive finding from imaging, histology or body fluid analysis along with a biopsy. At this stage, rifampicin resistance was also checked for MDR-TB cases. LFTs levels were also checked. Eligible participants were adults aged 18 or over with TB who met the eligibility criteria for anti-TB therapy, in accordance with the WHO recommendations [20]. We excluded newly diagnosed cases who had refused to participate in the DOTS mobile outreach team intervention and visiting patients (mostly pilgrims) from other countries/cities. In addition, we also excluded HIV positive and MDR-TB cases from our study, as the literature indicates a higher rate of patients who are lost to follow up in such groups, which have been a source of potential bias [2,21].

2.3. Study intervention

Participants (TB patients) randomly assigned to the intervention group were served by mobile outreach teams for DOTS (i.e. administration of anti-TB medicines orally at the place and time of their choice and convenience under the direct supervision of the mobile outreach teams).

Those assigned to the control group received the conventional facility-based treatment under the DOTS recommendations. Following a protocol set by the Ministry of Health, a standardized health education presentation, using flip charts, about TB, its treatment, and the consequences of not completing the recommended course of treatment was presented to patients during their initial clinic visits. Both groups were given this presentation.

2.4. Randomization and masking

A research coordinator at the PHCC enrolled and assigned eligible TB patients to the two groups, using randomly generated sequences in opaque sealed envelopes. The details of the series were unknown to any of the investigators or the coordinator. A total of 200 (100 in each group) TB patients were randomly assigned to one of the two parallel groups, having obtained their informed consent, initially in a 1:1 ratio, to receive treatment by means of either one of the two management approaches under the DOTS regimen. Study investigators, research coordinators, statisticians and the patients were kept blind to allocation. However, due to the nature of our research, maintaining this ignorance at the intervention phase was not possible, as both patients and physicians were aware of the group to which each patient had been allocated. The statistician, however, was kept blind to the allocation. As has been said, written informed consent was taken from the patients, and they were assured that the data collected would remain confidential.

2.5. Study Outcomes

The primary outcome was represented by the measure of the overall treatment success rate (completed treatment + cured pulmonary TB patients or completed treatment + cured extra-pulmonary TB cases), according to the global standards for assessing anti-TB programs [2,21]. "Treatment completion" meant that the patient had completed the prescribed course of medication, "patient cured" meant that the patient had had at least three consecutive negative sputum Acid-Fast Bacilli (AFB) smear tests, as well as having completed the treatment, and "default rate" refers to patients falling into three categories; those who did not complete the treatment, or those whose AFB results were incomplete, or those patients who were lost-to follow-up [2,21].

In addition to quantifying the overall success rate of their treatment, as secondary outcomes for each category, patients were also assessed on cured rate, treatment completed, lossto-follow-up rate, and the acceptability and effectiveness of the intervention. Those who had died during the study period made up a separate category. Details of patients moving/ transferred out of Jeddah were passed on to that region's TB control program for treatment continuation. No patient under treatment was deported during his medication course.

We followed the TB patients for up to six months of their anti-TB treatment course to determine the outcome variables. In addition, periodic physical and sputum examination for AFB were carried out at two, four and six months of treatment on both groups.

2.6. Sample size calculation

Initially, it was thought that all the diagnosed TB patients during the study period would be included, but because of logistical restraints, the sample size was restricted to 100 in each group. We estimated that a total of 170 TB patients would be needed to detect a 10% difference (taken from a regional study [2]) over a 6–8 month period between the groups, with a two-tailed α of 0.05 and a $(1-\beta)$ of 0.80 using the formula $n = (Z\alpha + Z\beta)^2 \times (p1 \times (1 - p1) + p2\,(1 - p2)/(p2 - p1)$. We, therefore, increased the sample size to 221 to account for an estimated 30% attrition rate.

2.7. Statistical analysis

Our primary analysis was conducted using an intention-to-treat approach and therefore included all the randomly selected TB patients. Baseline characteristics of patients in the two treatment groups were reported, using frequency distributions and descriptive statistics. A Chi-square test was used to measure any significant difference between

the two groups. Binary logistic regression model [using a backward stepwise (likelihood ratio) method] was performed to evaluate the predictors for overall success after controlling for age, gender, smoking status, nationality, and educational status. A P value < 0.05 was considered significant. Odds ratio estimation examined the effect of mobile outreach teams in the treatment success rate, using a 95% confidence interval. Kaplan-Meier with log-rank test was used for comparison at the end of six months. All analyses were conducted using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA).

2.8. Deviation from study protocol

An environmental survey could not be undertaken in the intervention group as the mobile team did not always meet patients in their houses. Drug side effects were also not documented.

3. Results

Between November 1st, 2017, and November 1st, 2018, a total of 221 newly diagnosed TB patients were screened for eligibility for the study and asked whether they would participate in it. Of the total, 16 were found to be ineligible and five simply declined. The remaining 200 subjects who met the eligibility criteria were consequently enrolled in the study and randomly assigned to either the intervention or the control group (Fig. 1). Around 97 patients in the intervention group and 76 patients in the control group completed the trial and were included in the final analysis. The overall response rate was 86.5% (173/200). A response rate of the intervention group was 97% compared to 76% of the control group. Reasons for lost-to-follow-up are given in Fig. 1.

The mean age of the study participants was 34.85 ± 12.94 years. In our study, the majority of participants were male (n = 133, 66.5%). Around 29.0% (n = 58) were Saudi nationals, followed by Yemenis at 18.5% (n = 37), Chadians at 13.0% (n = 26), Pakistanis at 9.0% (n = 18), Ethiopians at 8.0% (n = 16), Somalians at 6.5% (n = 13), and other nationalities. These figures indicate the overall majority of non-Saudi patients, i.e. 71% (n = 142). However, no significant difference was reported in the default of Saudi and non-Saudi participants (p = 0.594). Saudi female patients accounted for 21% (n = 14) of subjects as compared to 79% (n = 53) female patients of other nationalities. Pulmonary TB was the most prominent TB site n = 161 (80%), with a few cases of extra-pulmonary TB n = 39 (20%) thrown in. No significant difference was noted between educational status and the lost-to-follow-up rate (p = 0.245). Socio-demographic group characteristics of our respondents are shown in Table 1.

Around 77% (n = 152) of patients were unable to identify any potential source of infection. Only 15.5% could identify family members, friends or prison cellmates as the source of their disease. The majority of the participants reported living, working or shopping in non-crowded areas (Table 2). Sun exposure and ventilation status were also reported to be adequate, as given in Table 2.

Sheesha/Hukkah smoking was noted in nine (4.5%) individuals, current cigarette smoking was reported by n = 16 (8%) patients and n = 19 (9.5%) claimed to have quit smoking. Around n = 11 (5.5%) participants had a past history of TB infection (they were therefore relapsed patients) and out of these, only two (1.0%) did not complete their treatment. The majority 52% (n = 104) remembered having been previously vaccinated against tuberculosis, but 12.5% (n = 25) could not recall any previous inoculation.

The overall success rate was higher in those participants served by the mobile outreach team, with a low loss-to-follow up rate, as is shown in Fig. 2. The ratio of overall treatment success among those patients served by the mobile outreach teams was higher than that of the patients in the control group (ratio = 1.27, CI = 1.13–1.43). Based on their last three consecutive negative AFB results and the completion of their treatment regimens, the cure rate was around 30% in the non-mobile

team served patients, and around 60% in the mobile outreach team served patients. The loss-to-follow up rate in the control group was around 24% (Fig. 2).

The treatment dropout rate in the intervention arm was significantly low compared to the non-mobile team served TB patients (p < 0.001). Table 3 demonstrates the regression analysis model to highlight the factors predicting overall success after controlling for the covariates like gender, nationality, smoking status, educational status and TB of type. Individuals served by mobile teams were around 11 times more likely to have an overall treatment success compared to control arm (OR = 11.08, CI = 3.15–38.99). Chi square results of sequential sputum AFB analysis demonstrate significant difference between the two groups at three-time intervals (Table 4).

Fig. 3 illustrates the Kaplan Meier analysis of default over time in the two treatment groups. The default was prominent after three months of treatment in the control arm with a sudden dip indicating a higher default rate. A significant difference in the default rate was observed after six months of treatment (log-rank statistics = 18.91; df = 1; p < 0.001).

No significant difference was noted in the default and success rate of Saudi and non-Saudi patients (p = 0.594). The mobile outreach teams were assessed based on their skills, competence, management, and administration. The majority of the patients were highly satisfied with all professional competences of the teams (around 90% approval of skills/competence and 82% of the management/administration of the project). No mobile outreach team-served individual was in the 'unsatisfied' category. The majority were satisfied with the monitoring of the mobile outreach teams by the Public Health Department (95%) and were willing to recommend this program to any friend or family member in future (93%). The percentage of patients meeting mobile outreach teams just to get their medicines was high 43% (n = 43). All the study participants in both groups proclaimed themselves satisfied with the health education sessions.

4. Discussion

The purpose of this study was to examine the impact of a new treatment strategy for TB patients, tailored to reduce the default rate, and to improve patient treatment outcomes. The results demonstrate that this new community mobile outreach team method was effective in increasing the treatment success rate and was received favorably by the patients themselves. The high treatment success rate of 97% in our study was better than the 92%, 90% and 83% successes achieved in Riyadh (KSA) [2], Myanmar [22] and Pakistan [23] respectively. This was probably because the patients under mobile outreach team supervision were more likely to experience treatment success, when compared to the control group. The main purpose of the mobile outreach teams, according to the DOTS recommendations, was to ensure that patients were administered their drugs under the direct supervision of a healthcare worker [23]. Personal monitoring of patient drug regime adherence by the members of mobile outreach teams resulted in a significant decrease in default rate among these patients. The high recovery success rate appears to justify its incorporation into future NTCPP activities.

In the non-intervention group, the treatment success rate was 76%, which corresponded to the 78% success rate reported by Ali et al. [24]. However, the traditional DOTS treatment success rates in some developed countries like the United Kingdom [25] and the USA [26] were 92% and 87.2% respectively. A higher success rate in developed countries can be attributed to superior health care systems, coupled with better patient health education and better awareness among patients of the importance of treatment completion and the associated complications in the event of non-completion [25,26]. However, our 76% success rate was much better than the 60%-69% rates mentioned in some South African and Indian studies [27–30]. This high rate of treatment failure in the control group was attributed to a notable number of treatment defaulters, as despite following and ensuring routine follow-up protocols,
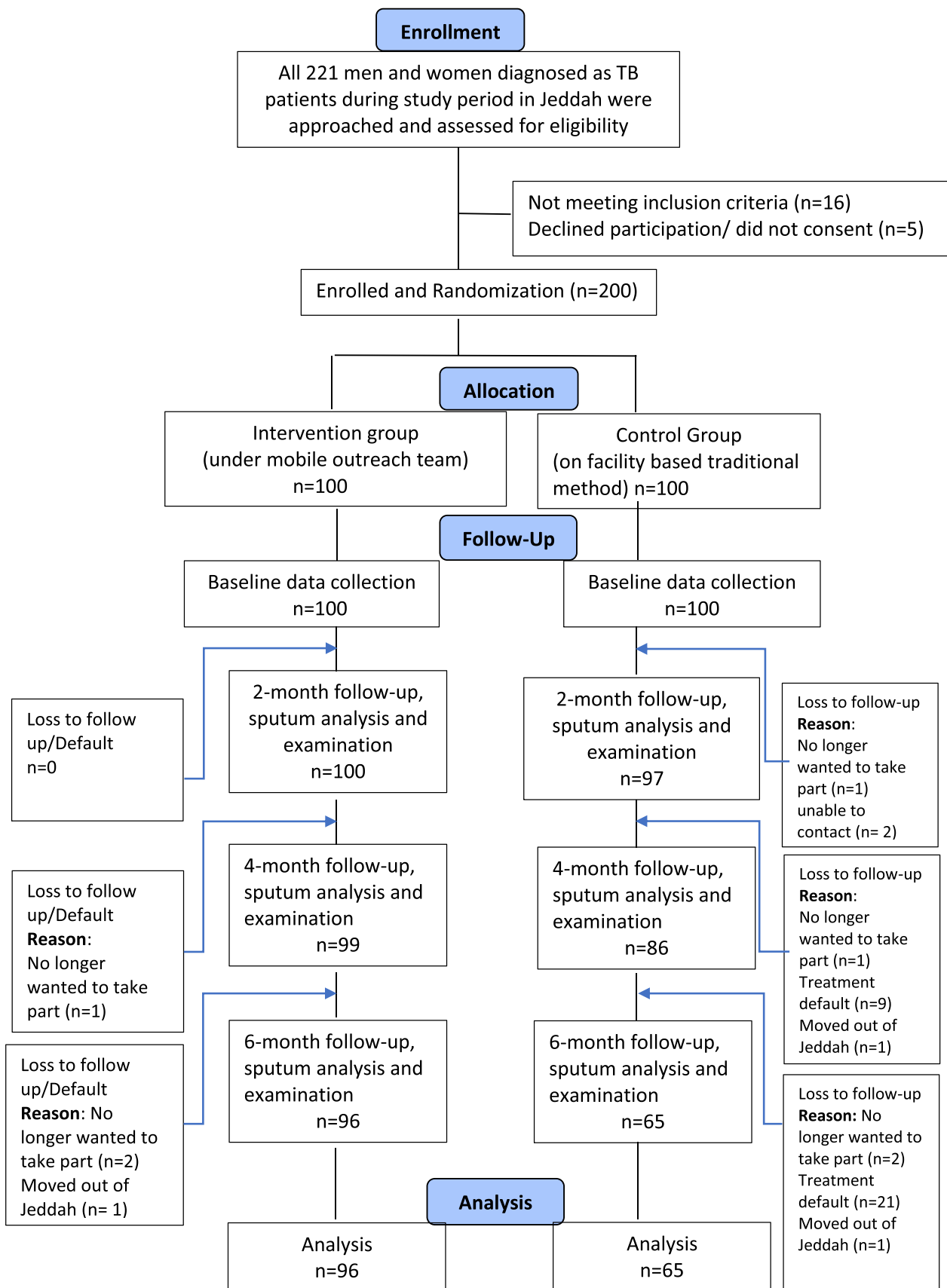
Fig. 1. Flowchart from the recruitment to the completion of the follow-up of the participants.

Table 1
Baseline socio-demographic characteristics of respondents (n = 200).

Characteristic		Intervention arm (n = 100)	Control arm (n = 100)	P value
		n (%)	n (%)	
Age (Mean ± SD)		34.76(±13.05)	34.94 (±12.88)	0.922[†]
Gender	Male	64 (64%)	69 (69%)	0.454*
	Female	36 (36%)	31 (31%)	
Nationality	Saudi	32 (32%)	26 (26%)	0.792*
	Non-Saudi	68 (68%)	74 (74%)	
Educational status	No formal education or till Primary	68 (68%)	68 (68%)	0.188*
	Till grade 10th	19 (19%)	23 (23%)	
	Till grade 12th	12 (12%)	8 (8%)	
	Bachelors and above	1 (1%)	1 (1%)	
TB type	Pulmonary	75 (75%)	86 (86%)	0.052*
	Extra pulmonary	25 (25%)	14 (14%)	
Smoking status	Current smoker	22 (22%)	3 (3%)	<0.001*
	Non smoker	78 (78%)	97 (97%)	

[†]Independent T Test.
* Chi-square test.

Table 2
Participants living conditions stratified by intervention (n = 200).

Variables		Intervention arm (n = 100)	Control arm (n = 100)	P value
		n (%)	n (%)	
Living conditions (household crowding) ≥ 2 people per room	Yes	54 (54%)	61 (61%)	0.317
	No	46 (46%)	39 (39%)	
Patient living in last 6 months	Jeddah	95 (95%)	100 (100%)	0.274
	Outside Jeddah	5 (5%)	0 (0%)	
Expected source of infection	Unknown	65 (65%)	87 (87%)	0.027
	Prison mate	6 (6%)	3 (3%)	
	Neighbor	2 (2%)	1 (1%)	
	Hospital	2 (2%)	1 (1%)	
	Family member /friends	18 (18%)	5 (5%)	
	Work place	6 (6%)	2 (2%)	
	Sheesha cafe	1 (1%)	1 (1%)	
First contact with the source	Unknown	65 (65%)	87 (87%)	<0.001
	<5 months	18 (18%)	3 (3%)	
	5 months to 1 year	7 (7%)	8 (8%)	
	More than 1 year	10 (10%)	2 (2%)	
Residence/ Presence in crowded places	Yes	15 (15%)	11 (11%)	0.400
	No	85 (85%)	89 (89%)	
Work in crowded places	Yes	23 (23%)	12 (12%)	0.041
	No	77 (77%)	88 (88%)	
Shop in crowded places	Yes	6 (6%)	9 (9%)	0.421
	No	94 (94%)	91 (91%)	
Open windows regularly	Yes	87 (87%)	86 (86%)	0.836
	No	13 (13%)	14 (14%)	
Sun exposure	Yes	87 (87%)	89 (89%)	0.663
	No	13 (13%)	11(11%)	

our staff was unable to contact them. Literature has identified illegal migrants mostly as defaulters, who after initial improvement of symptoms are then unable to be traced [2,5,13].

Our findings provide evidence that TB cure and treatment completion was lower in the groups not served by means of DOTS therapy. The treatment completion rates of both groups were slightly lower than those in reported studies conducted in Riyadh [2] and Karachi [23]. However, the cured rate in our intervention group was 60%, which again was better than the 54% and 53% respectively in the Riyadh [2] and the Karachi [23] studies. The lost-to-follow-up rate of only 3% in our intervention group was much better than the approximately 8% and 10% rates described in the Riyadh [2] and Karachi [23] studies. Some other studies reported a lost-to-follow-up rate of 8–15% [30,31]. Bronner et al. [30] and Santha et al. [32] even reported a rate of 23% and 32% respectively. To deal with TB drug resistance and prevent future disease relapse, higher treatment cure and success rates are more desirable than completion rates [2]. Another possible reason for the improvement in our overall success rates could also be attributed to our patients' overall satisfaction with the mobile outreach team intervention.

The overall treatment success rate for treatment by the mobile outreach teams was relatively high, with a surprisingly high number of patients meeting the mobile outreach team members just to get their medicine. However, we observed that around 30% of TB patients in the intervention group did not present to undergo the sputum smear at six months. Although the number of those who did have the test was higher than the 52% of TB patients from the control group who did, the reasons why so many intervention group patients missed this test needs to be addressed. A possible explanation could be their unwillingness to undergo yet another test once the long treatment has been completed [2,33,34].

Although all foreigners seeking jobs and residency in the KSA have to undergo pre-employment TB screening in their home country, it is obvious that the efficacy of this program needs to be evaluated [15,35,36]. Amongst the male subjects in our study, non-Saudi males made up the biggest group of patients by nationality, and these patients most often come from countries with endemically high incidences of TB. Abouzeid et al. [15], Alzohairy et al. [35] and Heldel et al. [36] also reported a similar predominance of foreign TB patients. Migrant workers have hard lives everywhere in the world, and the KSA is no exception. Smoking, poor nutrition, living and working conditions with limited ventilation, and sun exposure can all contribute to disease transmission. Similarly, these migrant workers do not regularly use health care facilities either through ignorance or fear. Illegal immigrants in particular avoid such facilities for fear of being deported or even imprisoned [15,35,36]. Improved planning and implementation of TB control and preventive measures [36,37] are essential to the health of all people in the KSA, including these poor and often uneducated migrants, who can unwittingly be carriers of the disease. Periodic screening of the non-Saudi workforce would improve the case detection rate, thus ultimately reducing disease transmission.

The majority of our study participants had no idea about the source of their infection. However, a few recognized the source from household contacts. A smaller but sizeable number of ex-prisoners identified other incarcerated men or women as carriers of the disease. Prisoners are a high-risk population in the case of infectious diseases like TB, and unfortunately, their number is increasing globally [36,38]. Prisoners can not only transmit communicable diseases to other prisoners but once released, can also transmit them to the wider population [36,38]. Understanding the health risk posed by socially excluded individuals like prisoners is also becoming vital for disease control.

The strength of this study undertaken in Jeddah is that it was the first RCT which was designed to compare a new treatment regime, i.e. the use of TB mobile outreach teams, with the more commonly-used traditional clinic-based treatment regimen. The successful outcome of the project, as demonstrated by the increase in the number of patients cured and it's
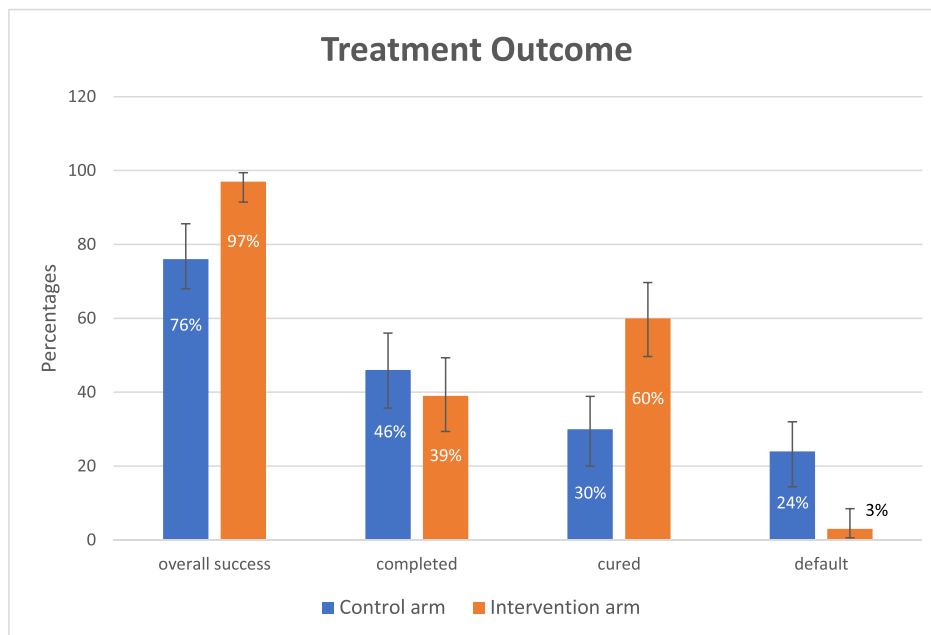
Fig. 2. Treatment outcome of intervention and control groups.

Table 3
Binary logistic regression analysis predicting factors for overall TB treatment success (n = 200).

Factors	Correlation coefficient (B)	Standard Error (SE)	df	Odds Ratio (OR)	95% Confidence interval
TB treatment group	2.40	0.642	1	11.08	3.15–38.99
Age	−0.04	0.017	1	0.957	0.927–0.989

*Adjusted for gender, nationality, smoking status, educational status and TB of type.

Table 4
Sequential sputum AFB analysis comparing intervention and control groups (n = 200).

Variables		Intervention arm (n = 100) (%)	Control arm (n = 100) (%)	P value
Sputum for AFB at time (0)	Negative	0 (0)	0 (0)	0.074*
	Positive	86 (86)	75 (75)	
	Not done	0 (0)	0 (0)	
	Extra pulmonary	14 (14)	25 (25)	
Sputum for AFB at two (2) months	Negative	69 (69)	74 (74)	0.001
	Positive	9 (9)	0 (0.0)	
	Not done	8 (8)	1 (1)	
	Extra pulmonary	14 (14)	25 (25)	
Sputum for AFB at four (4) months	Negative	57 (57)	72 (72)	<0.001
	Positive	1 (1)	0 (0.0)	
	Not done	28 (28)	3 (3)	
	Extra pulmonary	14 (14)	25 (25)	
Sputum for AFB at six (6) months	Negative	34 (34)	45 (45)	0.005
	Positive	0 (0.0)	0 (0.0)	
	Not done	52 (52)	30 (30)	
	Extra pulmonary	14 (14)	25 (25)	

*continuity correction

very positive reception by participants should encourage policymakers

in other cities to replicate it [2,39]. As previously stated, the HIV positive cases in our sample were not included in the trial as their immunocompromised status and the stigma attached to it were feared to potentially affect the outcomes and even the treatments themselves. According to some researchers, these patients are more likely to become lost-to-follow-up patients, thus reducing the bias [39]. Another strength of our study was the introduction of female staff members who could deal with female patients in our mobile outreach teams.

The study has a few limitations. Although the trial was designed to measure the overall success rate (cure) in TB management, we did not examine its cost-effectiveness by comparing the relative costs of transportation etc. with the costs of in-house treatments. Even with these limitations, a consensus exists that prompt diagnosis and adequate treatment is crucial for the prevention of drug resistance, relapse and for general disease control of TB [16,25,40]. It is therefore recommended and appropriate to include any intervention, including that of DOTS, that can ensure the completion of successful treatments of TB under the auspices of the Saudi NTCPP.

Another potential limitation of this study was that we did not carry out active case screening or contact tracing for our TB patients, nor was an environmental survey of the households involved undertaken. With many patients meeting the mobile outreach teams at a meeting point, instead of the teams always coming to their houses, it meant that team members were not always in a position to note environmental factors. Interpersonal difficulties between patients and team members (aggression or other deviant behavior patterns) were not assessed either, although a satisfaction survey was undertaken.

5. Conclusions

In conclusion, this study shows that the mobile outreach DOTS approach can be an effective and acceptable strategy for the treatment of TB patients. It also provides important data on the efficacy of using mobile outreach teams to improve TB treatment outcomes in Jeddah. Our results provide evidence and highlight the positive and significant impact of mobile outreach teams to be an effective strategy to mitigate TB default rates and improve TB treatment outcomes. With the growing number of cases of TB in the Kingdom, coupled with multi-drug resistant TB cases, and along with HIV co-infection, the need for a new strategy to improve treatment success and reduce patient treatment drop-out rates
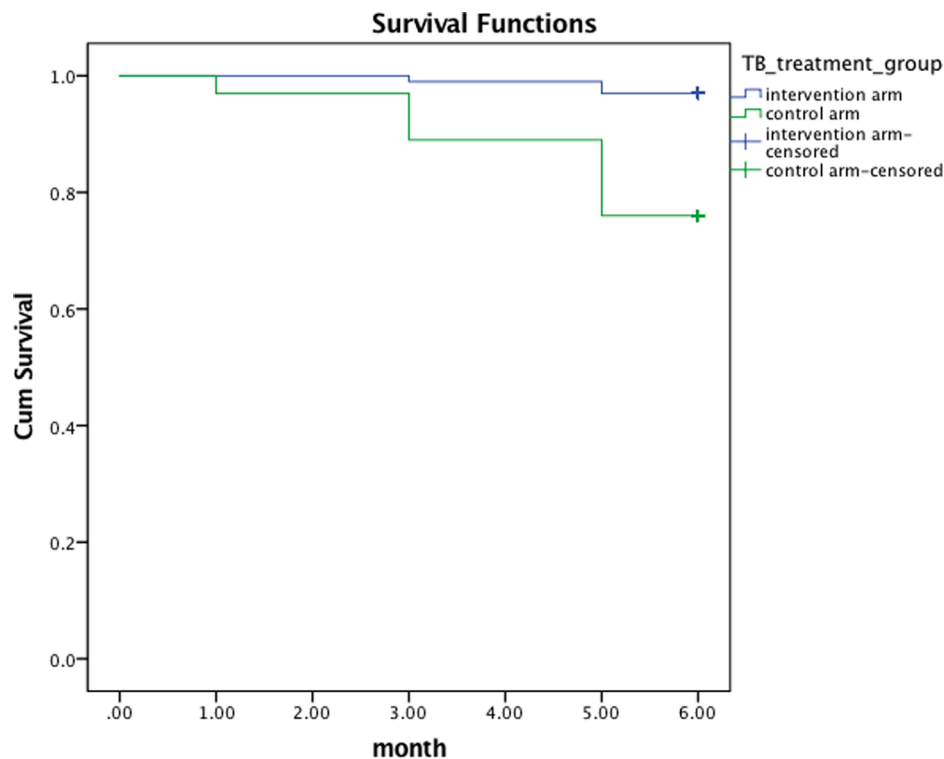
Fig. 3. Kaplan-Meier plot of the six months treatment duration.

is paramount. Since the effectiveness of the intervention has been demonstrated by its high success rate, the adoption of this mode of treatment for all TB patients in Jeddah, and its introduction in other cities of the KSA is recommended.

CRediT authorship contribution statement

Abdullah Al-Sahafi: Conceptualization, Writing - review & editing, Methodology. **Mashal M. Al-Sayali:** Writing - review & editing. **Najlaa Mandoura:** Writing - review & editing, Conceptualization. **Hassan B.U. Shah:** Writing - original draft, Methodology, Data curation, Conceptualization. **Khalid Al Sharif:** Conceptualization. **Emad L. Almohammadi:** Conceptualization, Project administration. **Ola A. Abdul-Rashid:** Conceptualization, Project administration, Writing - review & editing. **Muhammad Assiri:** Writing - review & editing, Resources, Supervision. **Mohammed F. Buksh:** Writing - review & editing, Resources. **Mahmoud M. Alali:** Proof reading, Conception and design the study. **Abdullah Al-Garni:** Writing - review & editing, Resources, Supervision. **Fatima Al-Garni:** Writing - review & editing, Resources, Supervision. **Abdullah Al-Zahrani:** Writing - review & editing, Resources, Supervision. **Alaa Khalawi:** Writing - review & editing, Resources, Supervision, Project administration. **Maha Alawi:** Writing - review & editing, Resources, Supervision. **Abdulhamed L. Moawwad:** Resources, Supervision. **Abdulrahim I.A. Almalki:** Resources, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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