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ORIGINAL ARTICLE

Central Line Bundle Care Approach: An Improvement Project in A Tertiary Care Hospital

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ABSTRACT

Background*: Central line-associated bloodstream infections (CLABSIs) can be avoided by implementing well-coordinated, evidence-based multimodal preventive strategies. Central line care bundle is a package to minimize CLABSI.* ***Objectives:*** *This study aims reduce CLABSI rate and to maintain that reduced rate in ICU units in a tertiary care hospital; and to improve the perception of core knowledge related to CLABSI prevention.* ***Methodology:*** *A prospective intervention improvement project was performed to reduce CLABSIs rate in an intensive care unit. The study was conducted in three consecutive phases. CLABSI rates were calculated throughout the three phases. Comprehensive initiatives for insertion and maintenance of CLABSI preventive bundles were coordinated through active educational and training programs.* ***Results:*** *CLABSI endemic rate per 1000 CL days dropped from 34.19‰ in phase I to 27.6‰ and 6.76 ‰ in phase II and III respectively. During implementation of our improvement project the overall compliance to CLABSI preventive bundles gradually increased from 35% at the beginning of phase II to 80%and 100% at the end of phase II and III respectively.* ***Conclusions:*** *Bundle approach for preventing CLABSI proved to be a very effective strategy.*

INTRODUCTION

Central venous catheters (CVCs) are life-saving and the majority of patients in intensive care units (ICUs) have them placed in order to receive fluids, medications and blood products as well as hemodialysis therapy and monitoring of the patient's blood pressure. However, the use of these catheters can result in serious and life threatening healthcare associated bloodstream infections that can lead to prolonged hospital stay, increased medical costs and increased risk of morbidity and mortality [1,2,3].

Central line associated blood stream infection (CLABSI) is a laboratory-confirmed bloodstream infection (LCBI) that arises on or after the third calendar day of a central line placement and central line is present on the date of LCBI (date of event) or the day before and is unrelated to an infection at a different location [4].

CLABSI risk can be significantly reduced through proper implementation of CL insertion and maintenance bundles according to CDC's Healthcare Infection Control Practices Advisory Committee (CDC/HICPAC) Guidelines [4,5].The care bundle approach as a quality improvement (QI) tool was introduced in 2001. Central line care bundle is a small group of evidence-based best practices that, when done collectively, will result in much better results than when performed individually [4]. Despite the availability of evidence-based strategies, CLABSI rates remain relatively high, according to the most recent studies. Low staff awareness, a lack of understanding of current information or a disagreement with it, inability to change institutional behavior, and deficiency of resources all contribute to insufficient implementation of prevention initiatives[2,6].

For the CLABSI preventive guidelines to be implemented successfully, multiple and different approaches for particular geographical or institutional contexts are required [7,8].

Implementing intervention programs requires both teaching and feedback from healthcare staff. The educational component should be designed in such a way that encourages healthcare personnel to cooperate, learn from, and support one another [5,7].

The goals of this improvement project were to reduce CLABSI rate and maintain that reduced rate in ICU units in a tertiary care hospital; and to improve the perception of core knowledge related to CLABSI prevention.

METHODOLOGY

This was a longitudinal study of patients admitted to the adult ICU in a tertiary care hospital, in Cairo, Egypt.

The study was done on 5 physically separated medical and surgical ICUs; the total number of beds was 50 separated by waterproof curtains. Each ICU has two sinks with dispensers containing plain liquid soap

and another for betadine foam 7.5%. Each sink has a dispenser for paper towels. Two isolation rooms serve the 5 ICUs. The ICUs have central ventilation system. It was covered by certified intensivist 24 hours a day, 7 days a week, with a nurse-to-patient ratio of 1:2 in day and night shifts. The ICU had an active infection prevention and control program that collaborated with the ICU medical and nursing staff to ensure proper implementation and monitoring of infection prevention and control practices.

This study was conducted in three phases from January 2018 to June 2020; a pre-intervention phase (Base line assessment) of 6 months (from January 2018 to June 2018); an intervention phase of one year (from July 2018 to June 2019); and post-intervention phase of one year divided into two sub-phases; i) maintenance; and ii) reassessment and auditing phases (from July 2019 to June 2020).

A multidisciplinary team was created to work on achieving and sustaining the targeted reduced CLABSI rates. The multidisciplinary team included the director of infection prevention and control (IPC) as a team leader, an intensivist as the co-leader, the other members included: IPC team, ICU doctors, and ICU nurses.

Phase I:

Pre-intervention phase (Base line assessment): January 2018 to June 2018 (6 months): Phase I included monitoring compliance to insertion and maintenance bundles of central line; and compliance to hand hygiene. CLABSI epidemiologic surveillance program is being carried out. The insertion bundle included: hand hygiene, maximal barrier precautions, alcohol-based chlorhexidine skin antisepsis, and optimal catheter site selection. Hand hygiene, catheter site dressing, hub care, and daily review of the necessity of CL were all included in the maintenance bundle. Care and dressing of the insertion site of the CL either sterile gauze or sterile commercially available transparent semipermeable dressing should be used and replaced every 48 hours and one week respectively; unless otherwise needed. Prior to gaining any access to the catheter hubs, 70% alcohol is used, to reduce contamination. The overall compliance to CLABSI bundle was considered zero even if only one of the five elements was not compliant [1,7].

The perception of core knowledge of insertion and maintenance bundles was assessed for all nurses and doctors in the ICU using a 10 questions questioner at the start of the pre-intervention phase and at the end of the intervention phase. Hand hygiene performance in ICU was monitored weekly by an infection control nurse using the World Health Organization hand hygiene five moments audit tool. Feedback about the hand hygiene performance was given to the health care workers immediately on the spot and monthly to each department[6, 7, 9].

Baseline designated surveillance for CLABSI was performed, one CLABSI definition was used which was based on that of the US Centers for Disease Control and prevention *(CDC, 2017)*. Aligned to microbiological results; CLABSI case definition was met when CL had been in place for more than two calendar days on the event date, and the line had been in place on the event day or the day prior.

The infection prevention and control team (IPC) members monitored the CLABSI events as well as compliance with use of the central line bundles. Rate of CLABSIs was calculated as number of infections per thousand CL days [4, 7].

Phase II (Intervention phase): (July 2018 to June 2019):

The multidisciplinary team adopted central line bundle to reduce CLABSI rates. The team met regularly to implement and coordinate the CLABSI prevention bundles prior to implementation. The team also reviewed the CLABSI events and discussed any issues with implementation of central line bundle and compliance to its elements and this continued throughout the intervention phase with corrective actions taken immediately until desirable outcome was achieved.

The infection control team designed the overall CLABSI prevention bundles checklists, hand hygiene performance check lists and the educational materials and adjusted them based on the feedback received at the regular meetings. The educational materials included; lectures, presentations, posters, and flyers. In addition, compliance to hand hygiene was monitored using WHO audit tool[10] . Educational and training sessions were carried out for all healthcare workers in the ICU before implementation of the central line bundle and throughout the study. These sessions discussed the detailed components of the bundle and surveillance process. Additional training sessions and workshops were held for the nursing supervisors on monitoring the process of central line insertion and filling the CL bundle form. The educational sessions were held for one hour at weekly intervals for one year throughout the intervention phase. In parallel, the multidisciplinary team prepared educational sessions about the indications of insertion and removal of CL which were conducted by the intensivist. On the implementation of the CLABSI preventive checklists.

Regular group feedback and immediate individual feedback were given. The checklists used in the insertion and maintenance bundles were incorporated into the medical record and feedback was given to physicians and nurses as well as heads of different ICU units.

The team also prepared an all-in-one set that has everything essential for each insertion of CL; ensured constant supply of alcohol and alcohol-chlorhexidine antiseptics in addition to abundant supply of hand

hygiene supplies as paper towels, soap and antiseptics. Display of posters calling for hand hygiene and compliance to CL bundle insertion and maintenance, distribution of handouts describing the initiative to nurses and intensivists and on-the-job training were also included in the context of intervention activities[7, 11].

***Phase III* (Post intervention phase): July 2019-June 2020 (one year):**

Post intervention phase **was divided into 2 sub phases; phase** i: maintenance and phase ii: reassessment and auditing. During phase III systematically fixed monitoring programs continued, which included compliance to hand hygiene, and CLABSI prevention bundles. Individual healthcare workers received daily feedback and evaluation for violations, and clinical departments received monthly assessment.

Surveillance for CLABSI events continued throughout the post intervention phase. During the maintenance sub-phase the educational and training sessions were possessed less frequently and education relied mainly on on-job training. In the audit and assessment sub-phase active educational and training **meetings** were not conducted anymore; quick briefings were given to **ICU staff during infection control rounds7, 8.**

Microbiological Techniques:

Blood samples for culture were drawn under complete aseptic condition by using of alcohol based chlorhexidine, previous to the initiation of antibiotic therapy whenever possible. If a blood sample was obtained through a catheter, the hub was disinfected with alcohol 70% [4, 5].

Blood culture was performed using BacT/ALERT Microbial Detection Systems (bioMérieux Inc., Durham, NC)[6] .

The organisms were isolated and identified based on standard microbiological techniques[12]. The susceptibility of the clinical isolates to some routinely used antibiotics was determined by the Kirby-Bauer disk diffusion method. Ampicillin, ciprofloxacin, ceftriaxone, ceftazidime, gentamicin, amikacin and meropenem were tested for *Enterobacteriaceae*. For testing *Pseudomonas spp:* Piperacillin- tazobactam, ticarcillin, amikacin, gentamicin, ceftazidime, ciprofloxacin, meropenem, and colistin, were used. For extended spectrum beta-lactamase (ESBL) detection among the members of *Enterobacteriaceae*; combined disk method using both cefotaxime and ceftazidime, alone and in combination with clavulanic acid, was performed. For ESBL production confirmation; five mm or more increase in zone of inhibition for either cefotaxime-clavulanic acid or ceftazidime-clavulanic acid disk compared to the cefotaxime or ceftazidime disk, respectively was used. Azithromycinc, clindamycin, cefoxitin, penicillin and trimethoprim-sulfamethoxazole were examined for *Staphylococcus* spp. Cefoxitin disk diffusion test was applied to detect methicillin-resistant *S.aureus* (MRSA), when zone of inhibition was ≤21 mm.[13]

Statistical analysis:

Statistical analysis was performed using the statistical package SPSS version 21.

Data were summarize as mean and standard deviations.

Qualitative data: CLABSI bundle compliance was presented as numbers and percentages.

One Way ANOVA test was used as a comparison test between more than two groups for continuous data.

P values less than 0.05 were considered statistically significant.

RESULTS

Patient's number with CL, ICU Bed days, CL days, number of patients developed CLABSI and CLABSI incidence between January 1st, 2018 and June 31st, 2020, are displayed in table 1. The trend of CLABSI endemic rate among the whole study period is shown in figure 1.

Table 1: Overview of CLABSI rates data among the 3 phases of the study

Phases	Month	Patients with central line (No)	Central line days	ICU Bed days (No)	Patients developing CLABSI (No)	CLABSI rate
Phase I pre-intervention Base line assessment	Jan 2018	144	596	1350	22	36.9
	Feb 2018	133	443	1390	15	33.8
	March2018	125	426	1592	15	35.2
	April 2018	117	476	1491	16	33.6
	May 2018	110	598	1520	17	28.4
	June2018	125	617	1549	23	37.2
Total		754	3156	8892	108	34.2 *
SD**						3.20683645
Phase II (intervention Phase)	July 2018	110	599	1530	22	36.7
	August 2018	139	619	1523	23	37.1
	Sep2018	112	597	1499	21	35.17
	Oct 2018	113	613	1494	22	35.88
	Nov 2018	190	618	1568	17	27.5
	Dec 2018	110	599	1500	16	26.7
	Jan 2019	117	620	1489	18	29
	Feb 2019	119	599	1521	15	25
	March2019	110	629	1556	15	23.8
	April 2019	119	622	1578	11	17.68
	May 2019	123	617	1587	12	19.4
	June 2019	111	632	1533	11	17.4
Total		1473	7364	18378	203	27.6*
SD**						7.3397318
Phase III Post intervention phase						
Phase IIIi Maintenance phase	July 2019	100	630	1522	5	7.94
	August 2019	110	599	1545	5	8.35
	Sep2019	99	621	1537	5	8.05
	Oct 2019	110	601	1568	5	8.32
	Nov 2019	111	610	1499	5	8.2
	Dec 2019	110	599	1543	4	6.68
Total		640	3660	9214	29	7.92*
SD**						0.629
Phase IIIii Reassessment and Auditing	Jan 2020	100	622	1547	4	6.43
	Feb 2018	100	629	1567	3	4.77
	March 2020	103	638	1444	4	6.27
	April2020	105	601	1399	4	6.66
	May 2020	110	624	1298	3	4.81
	June 2020	119	645	1201	3	4.65
Total		637	3759	8456	21	5.60*
SD**						0.95
Average (endemic rate) of phase III						6.7
SD of phase III**						1.43

*Average endemic rate of whole phase
SD**: standard deviation

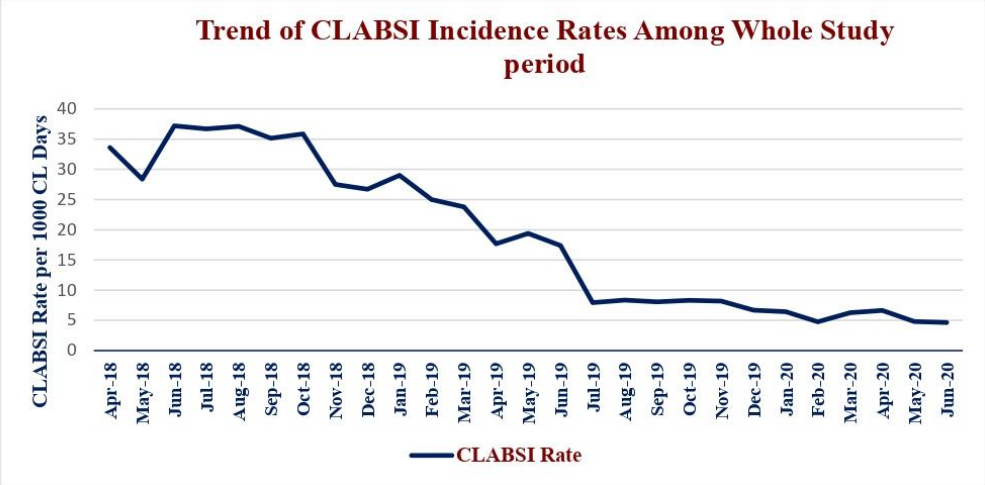
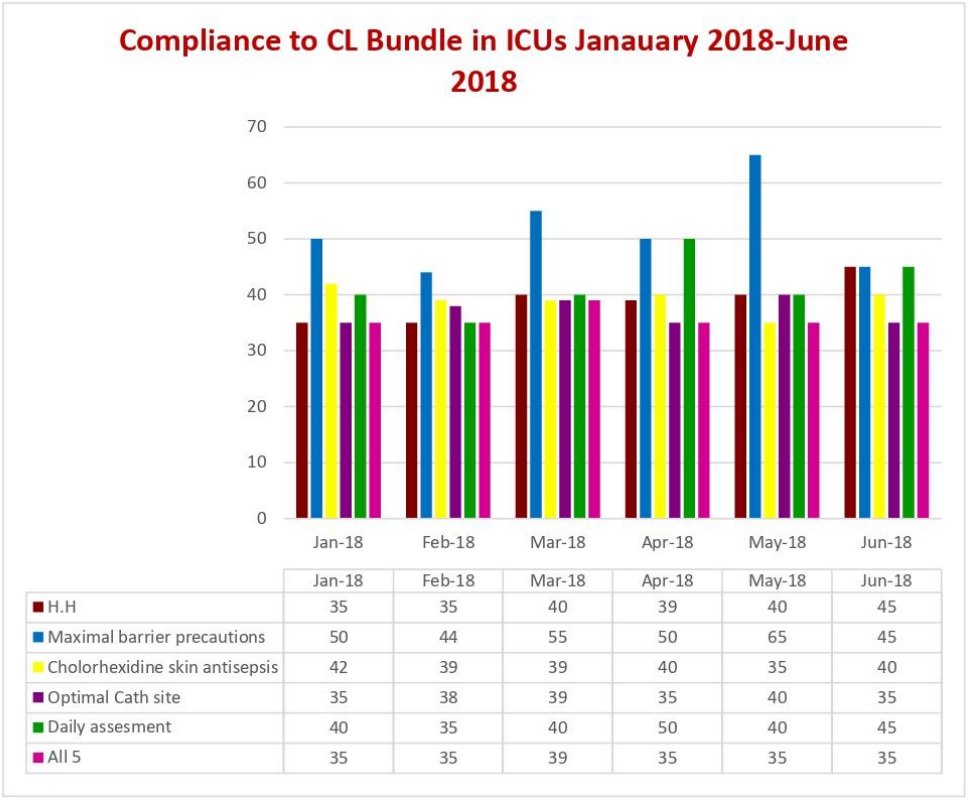


Fig. 1: Trend of CLABSI incidence rates among whole study period

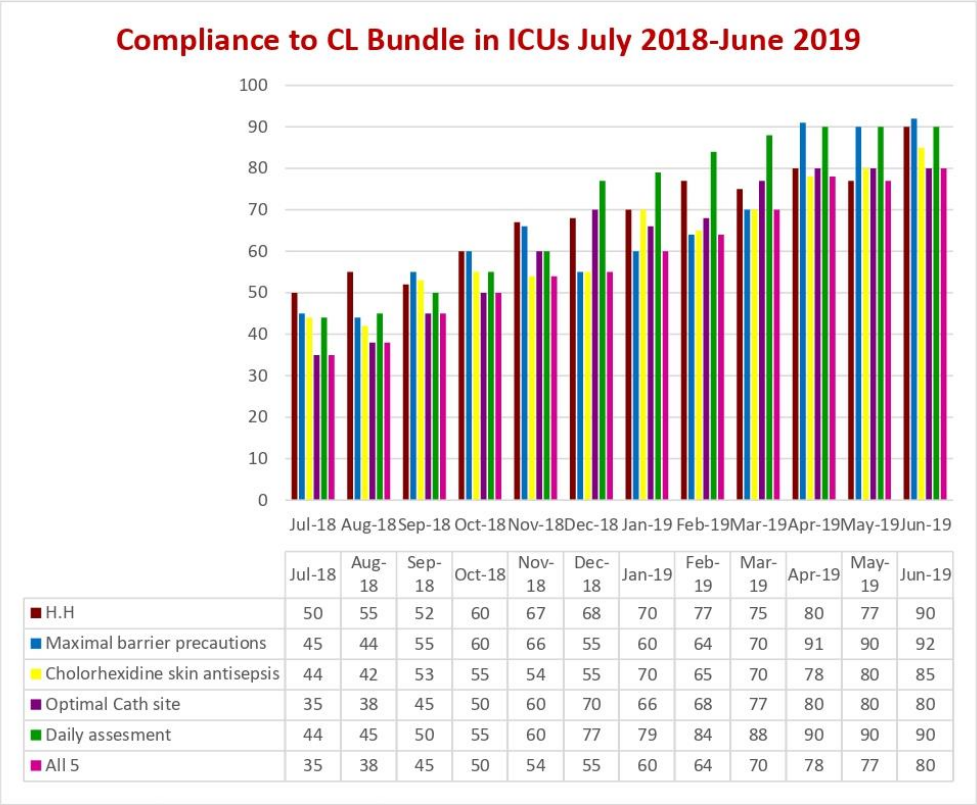
Compliance to each component of CL bundle in addition to the overall compliance to the all components of the bundle during first, second and third phases are shown in figure (2, 3, and 4).

The trend of CLABSI rate shows a considerable drop among whole study period (Fig1). As bundle compliance continued to rise optimally to 100%, a significant decline in the rates of CLABSI was observed (Fig 5).



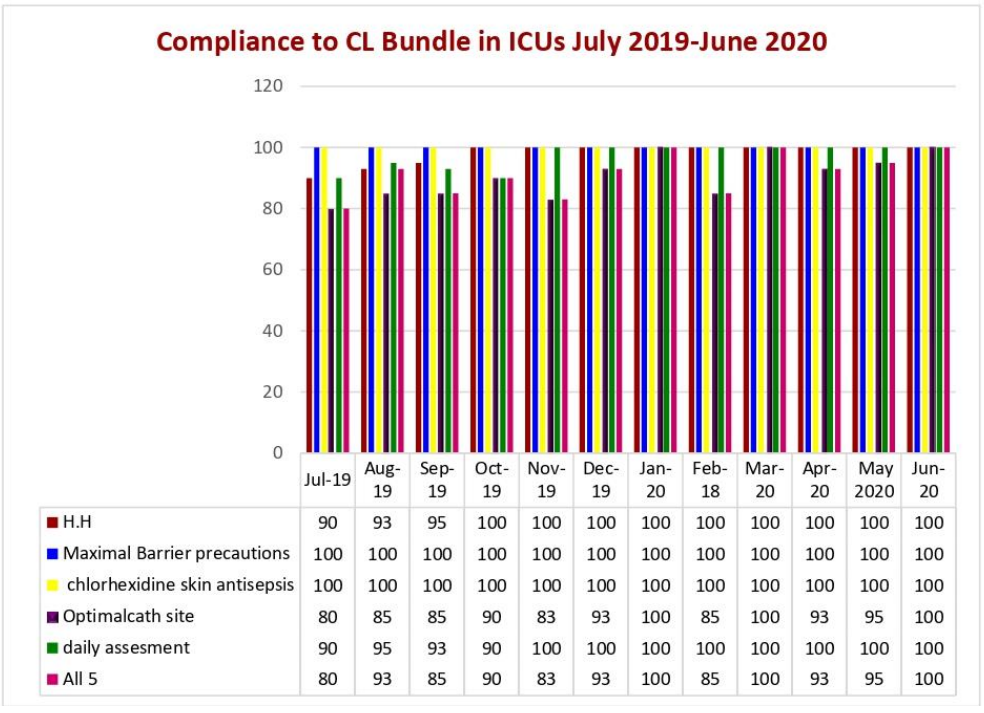
	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
H.H	35	35	40	39	40	45
Maximal barrier precautions	50	44	55	50	65	45
Cholorhexidine skin antisepsis	42	39	39	40	35	40
Optimal Cath site	35	38	39	35	40	35
Daily assesment	40	35	40	50	40	45
All 5	35	35	39	35	35	35

Fig. 2: Compliance to CL bundle in ICUs in phase I.



	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19
H.H	50	55	52	60	67	68	70	77	75	80	77	90
Maximal barrier precautions	45	44	55	60	66	55	60	64	70	91	90	92
Cholorhexidine skin antisepsis	44	42	53	55	54	55	70	65	70	78	80	85
Optimal Cath site	35	38	45	50	60	70	66	68	77	80	80	80
Daily assesment	44	45	50	55	60	77	79	84	88	90	90	90
All 5	35	38	45	50	54	55	60	64	70	78	77	80

Fig. 3: Compliance to CL bundle in ICUs in phase II.



	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-18	Mar-20	Apr-20	May 2020	Jun-20
H.H	90	93	95	100	100	100	100	100	100	100	100	100
Maximal Barrier precautions	100	100	100	100	100	100	100	100	100	100	100	100
chlorhexidine skin antisepsis	100	100	100	100	100	100	100	100	100	100	100	100
Optimalcath site	80	85	85	90	83	93	100	85	100	93	95	100
daily assesment	90	95	93	90	100	100	100	100	100	100	100	100
All 5	80	93	85	90	83	93	100	85	100	93	95	100

Fig. 4: Compliance to CL bundle in ICUs in phase III

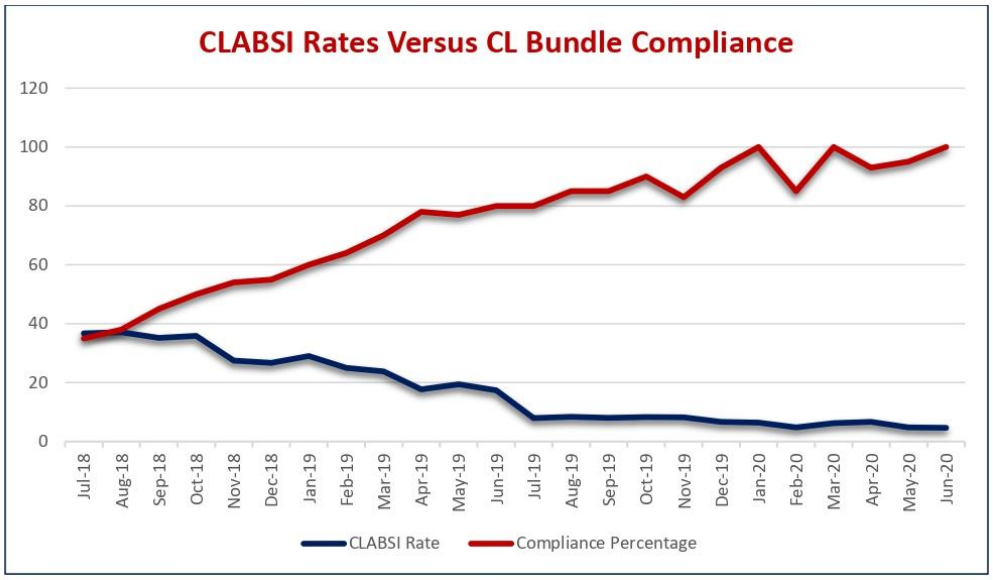


Fig. 5: CLABSI rates versus bundle compliance in phases II and III

The CLABSI endemic rate during the first phase was 34.19‰ CL days; and dropped to 27.6 ‰ CL days in the second Phase. The actual decline in the CLABSI endemic rate was attained in the third phase (6.76‰ CL days); when the compliance to bundle reached up to 80% and 100 % at the completion of the second and third phases respectively

Figures 6, 7 and 8 show the trend of CLABSI rates throughout the whole study period

The endemic rates for phase I, II, and III were (34.2, 27.6and 6.7 respectively), the upper control limits for phase I, II, and III were 40.6, 42.2 and 9.8 respectively and the lower control limits for phase I, II, and III were 27.8, 13 and 3.9 respectively.

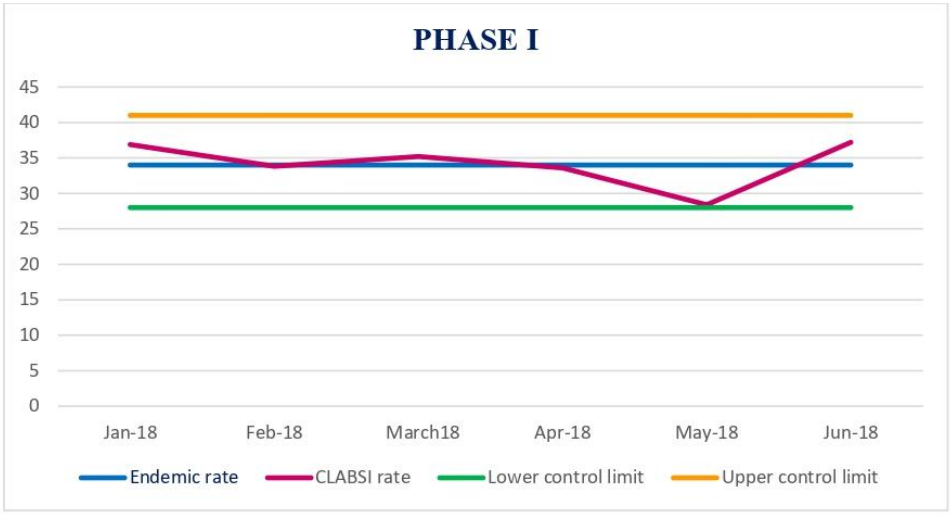


Fig. 6: Control chart of phase I

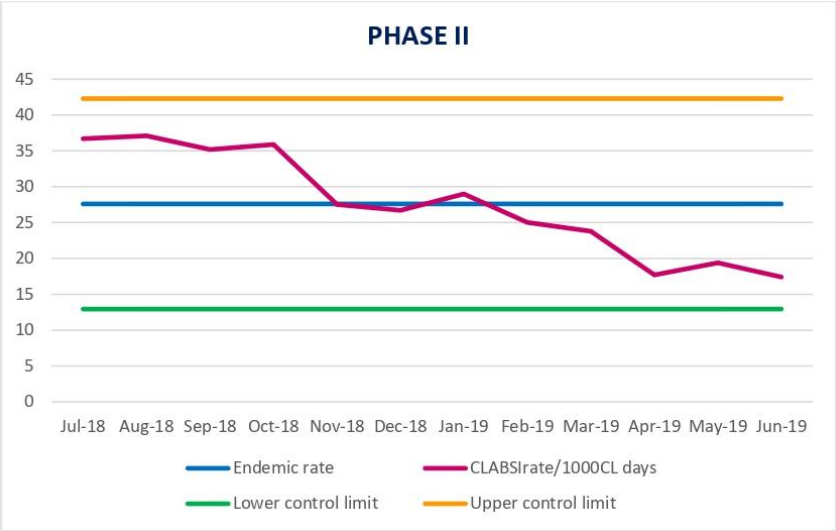


Fig. 7: Control chart of phase II

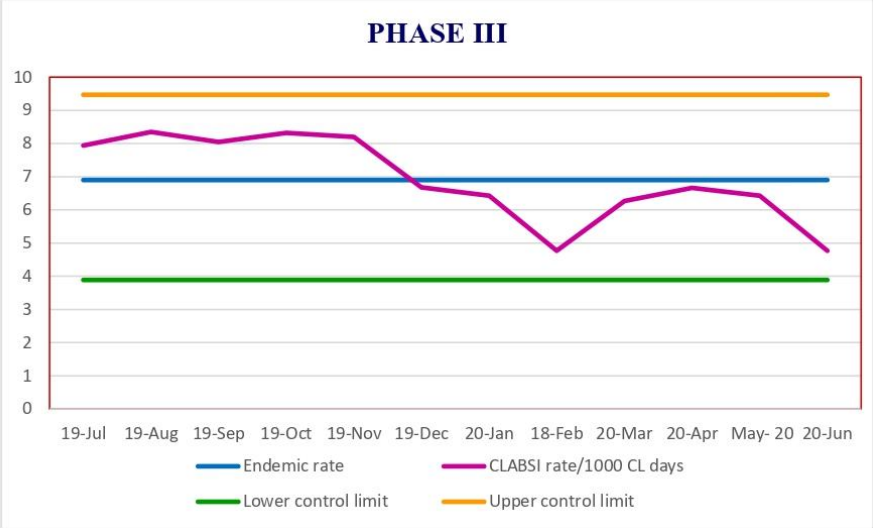


Fig. 8: Control chart of phase III

*The CLABSI endemic rate in phase I is considered the total infection rate (100%); therefore the percentages of CLABSI endemic rate of in phases I, II and III were 34.2/ 34.2= 100%; 27.6/34.2 =80.75% and 6.7/34.2 =19.7% respectively (table 2).

The difference in CLABSI endemic rate between the three phases was statistically highly significant p value<0.001

Table 2: Percentage of improvement of CLABSI rates in phase II and III as compared to phase I:

	Phase I pre-intervention Base line assessment	**Phase II (intervention Phase)**	**Phase III Post intervention phase**	**P value**
Endemic rate of CLABSI ± (2 S.D.)*	34.2 ±(6.4)	27.6±(14.6)	6.7±(2.8)	
Percentage Of Endemic Rates Of CLABSI (%) *	100	80.75	19.77	<0.001
Percentage of improvement in CLABSI rate***		19.25%	80.23%	<0.05

The percentage of improvement in the rates of CLABSI in phase II and III in comparison to phase I were statistically significant p value<0.05 (Table 2).

Throughout the total period of the research, the commonest microorganism causing CLABSI was *Klebsiella* followed by *CONS* (202/361 isolates; 55.9% and 66 /361 isolates; 18.2% respectively).The commonest multi drug resistant organisms (MDROs) were multidrug resistant gram negative bacilli (MDR-GNB) followed by ESBLs producing GNB (128/361; 35%and 68/361; 18.8% respectively).The total number of MDROs represented 66.2% of the total isolates (239 out of 361). The distribution of microorganisms for each phase is described in table 3.

Microbiology:

Table 3: Distribution of microorganism among 3 phases of the study*:*

Phase	Month	CONS	S.aureus	Klebsiella	E.coli	Enterococci	Acinetobacter	No of MDROs from all						No of organisms
								MRSA	MR-CONS	VRE	ESBLs	CRE	MDR GN	
Phase I pre-intervention Base line assessment	Jan 18	8	1	10	2		1	1	4		4	2	7	22
	Feb 18	5	1	8		1			4	1	4		4	15
	Mar 18	6		9					2		2		6	15
	April18	4	2	5	3	1	1	1	1		2	2	4	16
	May 18	6	1	7	1	1	1		1	1	4		4	17
	June18	8	2	10	1	1		1	2	1	4	2	5	22
	Total	37	7	49	7	4	3	3	14	3	20	6	30	107
Phase II (intervention Phase)	July 2018	6	1	10	3	1	1		3	1	5	2	5	22
	August 2018	5	1	11	4	1	1		4	1	4		6	23
	Sep2018	4	1	11	5		1		1		2		10	22
	Oct 2018	2		12	6	1	1		1	1	5		7	22
	Nov 2018		1	11	5						2		10	17
	Dec 2018			11	4		1				4		7	16
	Jan 2019			11	5	1	1			1	3		8	18
	Feb 2019	3	1	11				1	1		3		8	15
	March2019	2		11	1	1			1	1	4	1	6	15
	April 2019	2		5	4				1		1		2	11
	May 2019	2	1	6	2	1			1		2	1	6	12
	June 2019	1	1	6	2		1		1		3		5	11
	Total	27	7	116	41	6	7	1	14	5	38	4	80	204
Phase IIIi	July 2019			4	1						2		3	5
	August 2019	1		4							2		1	5
	sep2019			2	1	1	1				2		2	5
	oct 2019			3	1	1								5
	Nov 2019	1		4					1		2		2	5
	Dec 2019			3	1						1		2	4
	Total	2		20	4	2	1		1		9		10	29
Phase IIIii	Jan 2020			3			1				1		2	4
	Feb 2020		1	2							1		1	3
	March 2020			4							1		1	4
	April2020			3	1						1		2	4
	May 2020			3							1		1	3
	June 2020			2	1						1		1	3
	Total	-	1	17	2	-	1	-	0	-	6		8	21
Whole period	Grand total	66	15	202	54	12	12	4	29	8	68	10	128	361
	Percentage%	18.2	4.1	55.9	14.9	3.3	3.3	1.1	8	2.2	18.8	2.7	35	

DISCUSSION

Central venous catheterization has become the most important treatment in modern clinical medicine. CLABSI is a serious infection that has a lot of unfavorable consequences, including increased mortality, morbidity, hospitalization, and overall medical costs. However, the incidence of CLABSI decreases if strict sterile precautions were followed [4, 12]. As a result, many countries have implemented a CL care bundles, which includes hand hygiene, maximum barrier precautions, alcohol based chlorhexidine skin antisepsis, optimal catheter site selection and avoidance of the femoral site, a bundle checklist to supervise the catheterization procedure, and a daily assessment of line necessity with immediate withdrawal of unnecessary lines [4,14,14,12] .

This study described the processes and results of implementing the CVC care bundle from January 2018 to June 2020.

Rates of CLABSI were compared between the three phases of our study. CLABSI endemic rate dropped from 34.19 ‰ CL days in phase I into 27.6 ‰ CL days in phase II and 6.7 ‰ CL days in phase III after implementing bundle approaches for insertion and of CL. Statistically highly significant reduction in CLABSI rates between both phases II, III and phase I was detected. CLABSI improvement rates were 19.25 % and 80.23% in phase II and III respectively as compared to phase I. The percentage of improvement in CLABSI rate in phase II and III in comparison to phase I was statistically significant. Bundle compliance continued to rise to an optimum of 100%, with concomitant significant decline in CLABSI rate. The real reduction in the endemic rate of CLABSI was reached in the third phase (6.76‰ CL days); when the compliance to bundle achieved up to 80% and 100 % at the end of the second and third phases respectively.

Aligned to our results Gupta *et al.,* [10] *achieved an 87% reduction of* CLABSI rate from 3.1 ‰ CL days in the pre intervention phase to 0.4 ‰ CL days in the intervention phase by using an evidence based preventive bundle approach

Goldman et al.[15] *used* CLABSI bundle implementation as a part of hospital wide safety program. This program resulted in reduction in CLABSI rates from 1.9 to 1.3 per 1000 CL days with a maintained rate of improvement 30%.

In concordance with our results Lai et al. [14] who implemented a multidimensional CL bundle reported a significant decline in CLABSI rates by 12.2% (p value 0.001) in the intervention phase, from 5.74 per 1000 CL days in the pre-intervention phase to 5.04 per 1000 catheter days in the intervention phase.

In Taiwan, Lin et al.[16] published that CLABSI rates declined from 7.40 per 1000 CL days at baseline (before the CLABSI bundle was implemented) to 3.93 per 1000 central-catheter days after intervention ($p > 0.05$).

Yaseen et al.[1] conducted an improvement project in adult ICUs in Saudia Arabia in 2008, the CLABSI rate was 2.8 ‰ CL days at the beginning of the project then reached 0.7‰ CL days two years later and finally he achieved and maintained his target in 2014and 2015 (zero ‰ CL days)

As regards compliance to the five components of CL insertion bundle in our study we observed that the least compliance was to optimal catheter insertion site followed by using alcohol based chlorhexidine skin antisepsis (35% and 44%) respectively. However, a marked rise in the compliance to these two elements was achieved reaching optimally to 100% for each.

Similarly, Yaseen et al. [1] reported that the most defective bundle component in the start of their project was the choice of optimum insertion site (37%), but finally, compliance with this component had substantially improved (100 %). As bundle compliance continued to rise to an ideal of 100 percent, the CLABSI rate dropped dramatically.

Gupta et al. [10] reported similar improvement in compliance to CL bundle which went from 64% to 100%. Moreover they were able to sustain such improvement for more than three years.

Lai et al., [14] found that compliance rates for the optimal catheter insertion site were the lowest, (57.6%); which was consistent with our result. However, the second least compliant element in their study was hand hygiene; while alcohol-based chlorhexidine skin antisepsis was the second least compliant element in our study. This could be attributed to the shortage in supplying of this antiseptic therefore, compliance to this bundle element increased markedly and reached 100% finally as providing a constant supply of alcohol based chlorhexidine in the ICUs was a part of our improvement project.

Our results revealed that the commonest microorganism causing CLABSI was *Klebsiella* followed by *CONS* (202/361 isolates; 55.9% and 66 /361 isolates; 18.2% respectively). The whole number of MDROs represented 66.2% of the total isolates (239 out of 361).The most common resistant organisms were MDR-GNB, followed by ESBLs producing GNB (128/361; 35%and 68/361; 18.8% respectively). Abdelmoneim et al.[17] in Egypt reported that *Klebsiella* was the commonest isolated pathogens which represents 63.6 % (14 out of 22 isolates) followed by *Candida albicans* 13.6 % (3 out of 14 isolates) .

According to See et al.[18] in USA, coagulase-negative *Staphylococci* (16.9%) followed by *Klebsiella* species (12.4%) were the most prevalent microorganisms causing CLABSI in non-oncology settings. While the commonest isolated pathogen in

oncology settings was coagulase-negative *Staphylococci* (16.9%), followed by *Escherichia coli* (11.8 %).

Lin et al.[16] detected that the commonest microorganism responsible for CLABSI was *Enterococcus* species which represented 35 out 150 isolates (23.3%); followed by *Candida albicans* which represented 18 out of 150 isolates (12%). The resistant strains represented 26% from the total isolated pathogens.

The outcomes of developed countries were obviously significantly lower than those of the current study and prior studies in developing countries. This could be attributed to the stringent application of IPC measures and the ongoing annual surveillance of all hospitals, and rapid corrective actions, with the aim of lowering infection rates and approaching high-quality safe health care. The existence of resources, in addition to all health-care personnel awareness of infection-prevention and-control methods and a sufficient nursing-to-patient ratio, reduces workload and thus allows enough time to perform infection-prevention and-control techniques. The availability of long-term health-care facility units and home care services may also lead to shorter ICU stays and, as a result, lower rates.

Our approach for implementing CL bundles proved to be effective for many reasons. The approach was multidisciplinary which helped us identify the gaps in bundle implementation and hence customize our interventions and educational material. It also allowed us to better understand the high rates in CLABSI. All aspects of deficiencies were addressed as not all factors associated with higher CLABSI rates were related to ineffective infection control measures; as some causes were related to increased workload and insufficient nurse: patient ratio and shortage of some supplies as alcohol based chlorhexidine. Addressing these deficiencies had a major impact on improvement of infection rates. The educational sessions were held regularly with simulations and hands on training. In addition, educational material and approach were dynamically adjusted based on recognition of gaps and lack of knowledge as education went hand in hand with monitoring and observation of behaviors. Feedback was encouraged which helped us further improve our educational approaches.

However, our project was not without limitations; the most crucial of which was shortage of resources and shortage of some supplies, and difficulty in including all concerned HCWs in educational sessions due to their irregular schedules and part time jobs. In addition, it was difficult to evaluate the impact of each component of the bundle on infection rates and the identification of patient risk factors that could have attributed to the development of infection.

CONCLUSIONS

The implementation of best-practices central line insertion and maintenance care bundles significantly reduced CLABSIs. Application of an active surveillance program and proper data acquisition, evaluation, analysis, and interpretation of the results revealed good opportunities for improvement.

This manuscript has not been previously published and is not under consideration in the same or substantially similar form in any other reviewed media. I have contributed sufficiently to the project to be included as author. To the best of my knowledge, no conflict of interest, financial or others exist. All authors have participated in the concept and design, analysis, and interpretation of data, drafting and revising of the manuscript, and that they have approved the manuscript as submitted.

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