Quest Journals
Journal of Medical and Dental Science Research
Volume 8~ Issue 5 (2021) pp: 31-34
ISSN(Online) : 2394-076X ISSN (Print):2394-0751
www.questjournals.org

Research Paper

Kartik's Breathing Circuit (KBC) – A Novel Modified Breathing Circuit For Spontaneously Breathing COVID-19 Patients

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Received 09 May, 2021; Revised: 22 May, 2021; Accepted 24 May, 2021

To the Editor,

The ongoing coronavirus disease (COVID-19) pandemic situation is still accelerating and getting gloomy. The increasing number of patients and the severity of the disease increase the oxygen demand day by day. Consequently, exhaustion of surplus supply leads to a shortage of oxygen, which is a very dreaded situation. A spontaneously breathing and desaturating COVID-19 patient requires oxygen at very high flow rates (>15L) to maintain the desired SPO2 level. Higher oxygen flow results in wastage of precious oxygen and lots of aerosol generation in the surrounding environment. Many anesthesiologists are trying to tackle this situation using available anesthesia circuits such as Bain's circuit to provide oxygen at low fresh gas flow (FGF) levels. Bain's is not an ideal circuit in spontaneously breathing patients, so it needs to be modified. We assembled various components and connectors of available airway equipment and designed a unique circuit called the "Kartik's Breathing Circuit (KBC)" for spontaneously breathing COVID-19 patients. The KBC aims to create a pressurized oxygen reservoir in the circuit, avoid rebreathing, provide adequate oxygen at relatively low FGF rates, and create positive pressure during spontaneous breathing. The various components of this circuit include **(Fig.1)**,

1) **Jackson Rees (JR) circuit:** The JR circuit with the reservoir bag (500ml-1000ml capacity) in this system is used as an oxygen reservoir with a fully closed valve at the end.
2) **Fresh Gas flow:** It is the same FGF tubing as of JR circuit. The oxygen flowing through FGF can be diluted and humidified by connecting the FGF tube to the venturi connector and humidifier **(Fig.1C)**. As per our calculations, the required FGF for this circuit should not be less than minute ventilation (MV); otherwise, the reservoir bag will get collapsed after few breaths.
3) **Unidirectional valve:** Two unidirectional flap valves are used in this circuit. One valve is connected to the inspiratory limb distal to the FGF. Another valve is connected to the expiratory limb proximal to the heat and moisture exchange filter (HMEF). These valves maintain unidirectional flow, pressurize the circuit, and avoid rebreathing.
4) **T-piece:** It is connected distal to the inspiratory unidirectional valve. Two catheter mounts are attached to the T-piece to create the patient end and expiratory end of the circuit **(Fig.1)**.
5) **HMEF:** It is connected distally to the expiratory valve to filter expiratory air and avoid contaminating the environment.
6) **Mask**: Two types of masks are suitable for this circuit to provide pressurized ventilation. One can use a standard anesthesia mask (transparent) using a harness to create a proper tight seal around the face or a non-invasive ventilation (NIV) mask of appropriate size.

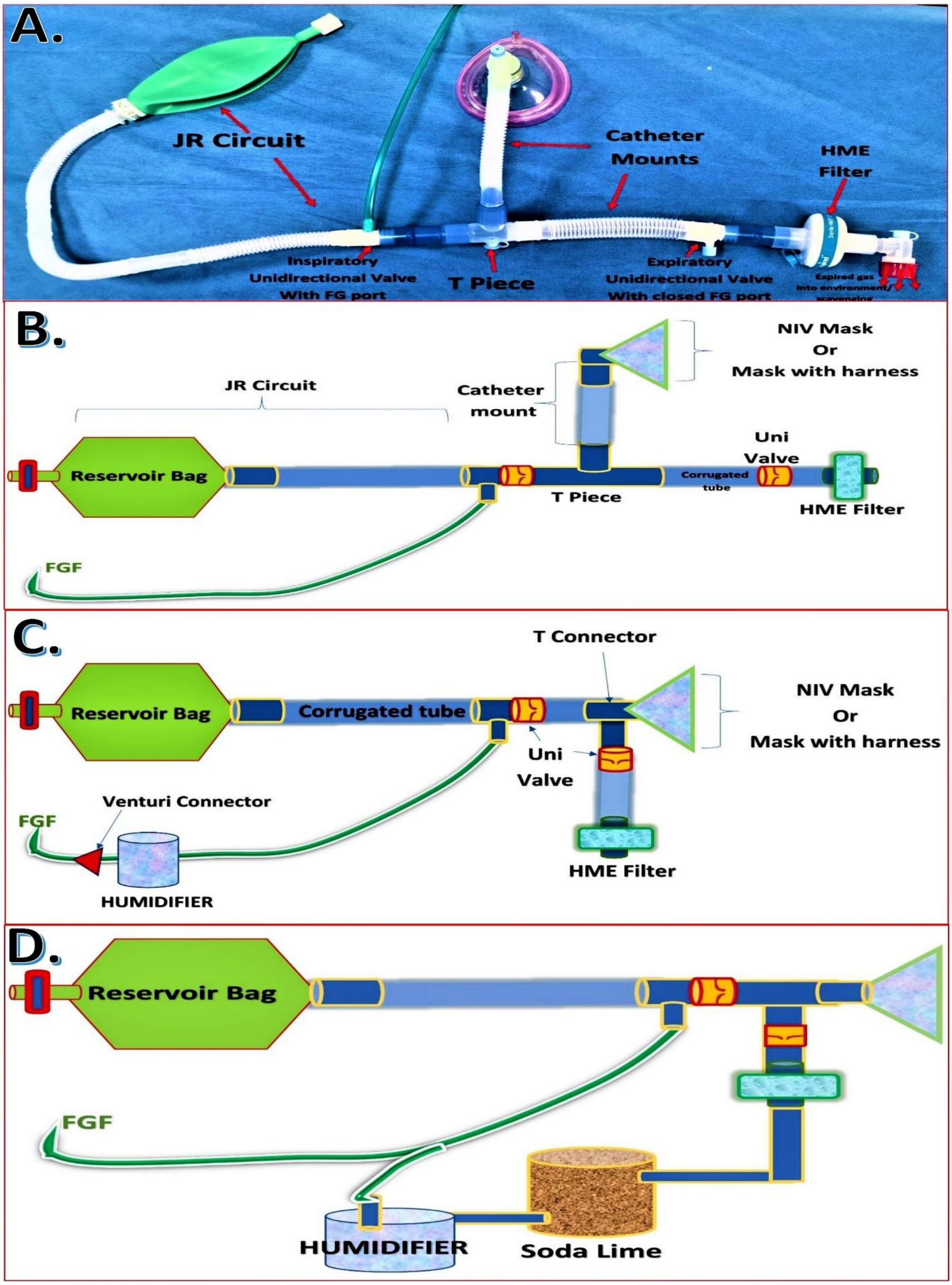

Figure 1: KBC model design, schematic diagram and modifications

- **A.** KBC assembly using actual components of airway equipments.
- **B.** Schematic representation of KBC assembly.
- **C.** Schematic representation of KBC modification removing one catheter mount and replacing T-piece with T-connector
- **D.** Schematic representation of KBC modification showing possible portable closed-circuit

Functional analysis of this circuit:

Before connecting to the patient, this circuit should be filled with oxygen by increasing FGF and closing other limbs (the patient and expiratory). After properly applying the airtight mask to the patient, the FGF can be adjusted based on the patient's weight and respiratory rate (**Table 1**). When the patient inspires, the FG from the saturated reservoirs (reservoir bag and corrugated tube of JR circuit) flow to the patient. During expiration, there is a continuous FGF into the system proximal to the inspiratory unidirectional valve. The expired gas flows towards the low-pressure area (expiratory limb) and will get filtered through the HMEF attached at the end of the expiratory limb. The positive expiratory pressure will close the inspiratory valve, avoiding mixing with the FGF. The inspired gas composition is determined by FGF, respiratory rate, tidal volume, end-expiratory pause, and CO2 production in the body. Factors other than FGF cannot be manipulated in a spontaneously breathing patient. As per our calculations, the FGF should be at least equal to the patient's minute ventilation to keep the system adequately pressurized.

Possible modifications:

We suggest two types of modifications in this described KBC. These modifications mainly aim to reduce dead space at the patient end, make the circuit more flexible, lightweight, and easy to use. We also tried to create a portable closed-circuit system (**Fig.1D)** by attaching a portable Soda Lime canister (customized) to use expired O2, further reducing FGF and oxygen wasting.

All the components of this system are readily available and easy to assemble. The unidirectional valves used in KBC are obtained from the reservoir bag of the poly mask (nonrebreathing mask). The current design of KBC is at a very premature level, subject to further modifications. The exact gas delivery and rebreathing can be checked using the flow sensors and ETCO2, respectively. We can also check its efficacy by doing arterial blood gas analysis at frequent intervals. Our aim in designing this circuit is to prevent wastage of precious oxygen and avoid contamination of the surrounding environment. However, further analysis and trials are required to check the efficacy of this circuit in COVID-19 patients.

WT (KG)	RR (/MIN)	TV (ML)	MV (ML)	RR CYCLE (SEC)	FGF (L/MIN)
10	15	70	1050	4	**1.05**
	20		1400	3	**1.4**
	25		1750	2.4	**1.75**
20	15	140	2100	4	**2.1**
	20		2800	3	**2.8**
	25		3500	2.4	**3.5**
30	15	210	3150	4	**3.15**
	20		4200	3	**4.2**
	25		5250	2.4	**5.25**
40	15	280	4200	4	**4.2**
	20		5600	3	**5.6**
	25		7000	2.4	**7**
50	15	350	5250	4	**5.25**
	20		7000	3	**7**
	25		8750	2.4	**8.75**
60	15	420	6300	4	**6.3**
	20		8400	3	**8.4**
	25		10500	2.4	**10.5**
70	15	490	7350	4	**7.35**
	20		9800	3	**9.8**
	25		12250	2.4	**12.25**
80	15	560	8400	4	**8.4**
	20		11200	3	**11.2**

	25		14000	2.4	**14**
90	15	630	9450	4	**9.45**
	20		12600	3	**12.6**
	25		15750	2.4	**15.75**
100	15	700	10500	4	**10.5**
	20		14000	3	**14**
	25		17500	2.4	**17.5**
110	15	770	11550	4	**11.55**
	20		15400	3	**15.4**
	25		19250	2.4	**19.25**
120	15	840	12600	4	**12.6**
	20		16800	3	**16.8**
	25		21000	2.4	**21**

Table 1: Fresh gas flow setting of KBC

WT: weight, **RR**: respiratory rate, **TV**: tidal volume, **MV**: minute ventilation, **FGF**: fresh gas flow

References:
None.

Contributorship Statement:

Dr. Kartik Sonawane[1], Dr. Hrudini Dixit [2], Dr. Tuhin Mistry[3], Dr. Chelliah Sekar[4]

K.S.: Designed novel KBC model circuit. With the guidance and approval of CS termed this technique as "Kartik's Breathing Circuit (KBC)." Designed manuscript content and co-wrote the paper. Took the lead in manuscript writing.
H.D. & T.M.: Co-wrote and proofread the manuscript. Took the second lead in manuscript writing.
C.S.: Approved idea by KS and provided scientific guidance for manuscript writing. Provided guidance for the content of the manuscript and Co-wrote the paper. Approved final version of the manuscript.
All authors provided critical feedback and helped shape the manuscript.