1. Introduction

In comparison to previous decades, undoubtedly marked improvements in pediatric medical technology and care resulted in improved survival rates and outcomes for critically ill children in India. Unfortunately, this improvement is not quantified in figures in our setup. In developed nations such as Australia, mortality of children below 5 years decreased from 260/1,00,000 to 137/1,00,000 in boys and from 221/1,00,000 to 111/1,00,000 in girls from 1907 to 1998 [1]. Sophisticated medical treatments and technology saved lives of many premature infants [2]. However, its impact relating to morbidity is not well documented. Although survival rates of these critically ill children who are medically fragile and technology-dependent have improved, we as health professionals are still in the learning curve to improve the quality of life of these children at home. Factors such as support from society, infrastructure, and funding play an important role in technology-dependent child care at home. In this review, commonly prescribed home-based medical technologies such as home ventilation, enteral nutrition, renal replacement therapy, and peripherally inserted central catheter, which are useful for quick revision, are described. In recent past, revolution in medical technology resulted in improved survival rates and outcomes of critically ill children. Unfortunately, its impact relating to morbidity is not well documented. Although survival rates of these critically ill children who are medically fragile and technology-dependent have improved, we as health professionals are still in the learning curve to improve the quality of life of these children at home. Factors such as support from society, infrastructure, and funding play an important role in technology-dependent child care at home. In this review, commonly prescribed home-based medical technologies such as home ventilation, enteral nutrition, renal replacement therapy, and peripherally inserted central catheter, which are useful for quick revision, are described.

2. Home ventilation

Common conditions that require home ventilation are shown in Table 1. Goals of home ventilation are to reverse or ameliorate the cause of respiratory failure, extend life span, reduce morbidity, and promote growth and development. Before discharging a child on ventilator support wholistic assessment of the child, family dynamics, family education and expectations, care provider’s confidence to handle emergencies, finances, electricity supply, telephone facilities, suitable entrances for wheel chairs, and local availability of medical facilities for emergencies needs to be considered. Home ventilation includes oxygen therapy, noninvasive ventilation, and invasive ventilation through tracheostomy. Before discharging a child on home ventilation, medical stability of the child should be assessed in acute care setting (Table 2) [16,17].
3. Oxygen [18]

Supplemental home oxygen is used for children with chronic lung diseases, such as bronchopulmonary dysplasia. Consider factors such as availability of space at home, mobility, expenses, and FiO2 requirement prior to discharge. Home oxygen can be supplied as liquid oxygen, oxygen cylinders, or oxygen concentrators. Advantages of liquid oxygen are: (1) liquid oxygen tanks are light and portable; (2) the duration of use is longer than oxygen cylinders; (3) they can be filled at home; (4) no need for electricity; and (5) no generation of noise or heat. Disadvantages are: (1) expensive and (2) companies often do not manufacture liquid oxygen.

Oxygen cylinders are commonly used for home oxygen therapy. Advantages are: (1) cylinders are cheaper compared to liquid oxygen, (2) various sizes of cylinders are available for use, (3) it is easy to carry smaller cylinders, (4) larger cylinders can be used for few weeks if the required flow is less than 1 L/min, and (5) no electricity required and no generation of noise or heat. Disadvantages are: (1) heaviness and need for frequent refilling.

Oxygen concentrators can be used in place of liquid oxygen or cylinders. Advantages are: (1) generate required oxygen concentration and (2) less expensive than liquid oxygen or oxygen cylinders.

Disadvantages: (1) not portable, (2) generation of heat and noise, and (3) high electricity costs.

In general, combination of oxygen sources is better to provide appropriate emergency backup and portability.

4. Noninvasive ventilation (NIV)

NIV refers to correction of hypoxemia or alveolar hypoventilation without the use of invasive artificial airways such as tracheostomy or endotracheal tubes. Interface is required for the delivery of NIV. Providing appropriate sized mask is one of the most difficult tasks in providing NIV to infants and children; as a result, a forced decision is made to perform a tracheotomy for providing ventilation. Interface include nasal pillow, nasal cannula, face mask, oronasal mask, helmet, etc. Usually NIV is used during nighttime unless the child suffers with progressive respiratory disorder or develops an acute decompensation where NIV requirement may increase to 24 h in a day. Patients with neuromuscular disorder or restrictive lung disease develop hypercapnic respiratory failure. NIV at nighttime can reduce daytime hypercapnea and symptoms of sleep-disordered breathing by reducing respiratory muscle fatigue, improving lung and chest wall mechanics, reversing microatelectasis, increasing chest wall excursion, and resetting CO2 sensitivity to central chemoreceptors in brain stem. Contraindications for NIV include inability to maintain patent airway, claustrophobia, inability to provide high pressures to maintain oxygenation or ventilation noninvasively, and inability of caregiver to provide NIV. Complications of NIV include poorly fitting interfaces, inadequacy of ventilation, eye irritation, pressure ulceration, and midfacial flattening. High flows may lead to nasal congestion, mouth dryness, aerophagia, and gastric distension. To avoid pressure injuries over the face, it is advised to have different styled interfaces, in-adequacy of ventilation, eye irritation, pressure ulceration, and midfacial flattening. High flows may lead to nasal congestion, mouth dryness, aerophagia, and gastric distension. To avoid pressure injuries over the face, it is advised to have different styled interfaces, inadequate ventilation, eye irritation, pressure ulceration, and midfacial flattening. High flows may lead to nasal congestion, mouth dryness, aerophagia, and gastric distension. To avoid pressure injuries over the face, it is advised to have different styled interfaces.
tracheostomy tube changes at predetermined frequency and in emergency as well [21,22]. It was seen that parents have the stress of taking the responsibility for providing tracheostomy care and in dignation by other healthy siblings when they receive less parental attention [23,24]. Recommendations for changing tracheostomy tube vary across the globe from once a week to once a month [25,26]. Frequently changing the tracheostomy tube reduces the risk for tube blockade and, in turn, infection [27]. Patients ventilated via tracheostomy require suction equipment. Portable suction machines are capable of developing pressures of 60–150 mmHg, which is recommended for airway suctioning. All children with tracheostomy should have self-inflating AMBU bag for use during emergencies. At authors’ unit, decision for tracheostomy is shared by otherhealthy siblings when they receive less parental attention [23,24]. Recommendations for changing tracheostomy tube vary across the globe from once a week to once a month [25,26]. Frequently changing the tracheostomy tube reduces the risk for tube blockade and, in turn, infection [27]. Patients ventilated via tracheostomy require suction equipment. Portable suction machines are capable of developing pressures of 60–150 mmHg, which is recommended for airway suctioning. All children with tracheostomy should have self-inflating AMBU bag for use during emergencies. At authors’ unit, decision for tracheostomy is shared between the clinician and patient’s relatives. Following which, tracheostomy procedure is initiated and child remains admitted in hospital for 7 days to allow the tracheostomy stoma to mature. Parents’ ability and determination to take care of the tracheostomy is thoroughly assessed by the clinician before discharging the child. Parents are taught the basic skills for tracheostomy tube care by the attending clinician, which include suction, change of the tracheostomy tube, and assessment of tube displacement and obstruction. The child’s clinical condition is explained to local otolaryngologist prior to discharge where the child resides.

Whenever possible, it is recommended to use relatively small tracheostomy tubes to allow peritubal leak to avoid tracheal damage and facilitate speech therapy. However, it should also be considered that large peritubal leak may lead to compromised delivery of airway pressures during ventilation. Peritubal leak can be tackled using pressure control mode of ventilation or using a cuffed tracheostomy tube with intermittent deflation. There should be a second tracheostomy tube of same size available for emergencies such as dislocation and blockage and another tracheostomy tube of one size smaller in case there is difficulty in reinserting during an unplanned tube change. For children who drool in excessive amounts may require extra tracheostomy tube holders to decrease skin maceration underneath the ties and allow for frequent tube changes. Positive pressure ventilation can be delivered by bi-level positive airway pressure (BiPAP) device, continuous positive airway pressure (CPAP) device, or portable ventilators. Differences between BiPAP/CPAP and portable ventilator are depicted in Table 4.

No single type of ventilator design is ideal for all patients. Patient’s clinical condition and ventilator characteristics are to be taken into consideration whenever a child is planned to discharge on mechanical ventilation.

5.2. Follow up

The frequency with which children need to be seen by the health care team depends on disease process, comfort level of treating team, and the ability of family to perform emergency interventions at home. At authors’ unit, once the child tolerates reduction in ventilator support in outpatient visit, the family is given appropriate instructions for reduction in respiratory support as well as trained to identify clinical indicators of intolerance after reduction of respiratory support. During every visit, changes in vital parameters, weight gain, tolerance for physical activity, sleep patterns, and overall mood are assessed, and if the child tolerates the reduction in support, orders are given for continued slow reduction of ventilator support and report to emergency room in case the child is uncomfortable with titration of ventilation support at home. Reductions in ventilator parameter setting are being done 1–2 times weekly. A 20% increase in heart rate or respiratory rate from baseline or failure to maintain adequate gas exchange as identified by oximetry and CO2 are indicators to stop further weaning. At authors’ unit, weaning from mechanical ventilation in case of reversible diseases begin either to CPAP or completely off support for 1–2 h in a day as per the child’s tolerance. The weaning trials are gradually lengthened in the awake state until the child breathes independently in waking state. Once the child tolerates weaning in the wake-up period, further reduction of support is done during naps and finally during sleeping hours overnight. As a point of care in authors’ unit, every child on tracheostomy tube changes at predetermined frequency and in emergency as well [21,22]. It was seen that parents have the stress of taking the responsibility for providing tracheostomy care and in dignation by other healthy siblings when they receive less parental attention [23,24]. Recommendations for changing tracheostomy tube vary across the globe from once a week to once a month [25,26]. Frequently changing the tracheostomy tube reduces the risk for tube blockade and, in turn, infection [27]. Patients ventilated via tracheostomy require suction equipment. Portable suction machines are capable of developing pressures of 60–150 mmHg, which is recommended for airway suctioning. All children with tracheostomy should have self-inflating AMBU bag for use during emergencies. At authors’ unit, decision for tracheostomy is shared between the clinician and patient’s relatives. Following which, tracheostomy procedure is initiated and child remains admitted in hospital for 7 days to allow the tracheostomy stoma to mature. Parents’ ability and determination to take care of the tracheostomy is thoroughly assessed by the clinician before discharging the child. Parents are taught the basic skills for tracheostomy tube care by the attending clinician, which include suction, change of the

| Table 3 | Complications of tracheostomy. |
|---|---|
| **Bleeding (intraoperative, early, and late)** | Intraoperative bleeding Postoperative bleeding Late arterial erosion |
| **Loss of airway/ability to ventilate (intraoperative, early, and late)** | Intraoperative inability to ventilate Decannulation before first tube change Inability to recannulate Tube blockade/disconnection Peritubal leak causing ineffective ventilation Respiratory arrest |
| **Air leak (intraoperative, early, and late)** | Pneumomediastinum Pneumothorax Subcutaneous emphysema |
| **Infection (early and late)** | Tracheitis Aspiration pneumonia |
| **Stomal issues (early and late)** | Skin erosion Infection Bleeding Breakdown Granulation tissue formation Keloid formation |
| **Tracheal problems (late)** | Tracheal/subglottal stenosis Tracheomalacia Tracheocutaneous fistula |
| **Others** | Esophageal injury (intraoperative) False tract creation (intraoperative, early, and late) |

| Table 4 | Differences between BiPAP and portable ventilator. |
|---|---|
| **BiPAP/CPAP** | Uses blower to generate flow and achieve desired pressure More easy to carry Better compensation for leaks Cannot generate high-peak pressures in case of worsening hypoxemia High rates of energy consumption No internal battery Rebreathing may be present due to single limb circuit for both inspiration and expiration |
| **Portable ventilator** | Uses pistons or turbines to generate desired volume or pressure Less easy to carry compared to BiPAP/CPAP Compensation for leak is not as good as BiPAP/CPAP Can generate high-peak pressures in case of worsening hypoxemia Low energy consumption Internal battery is present No rebreathing due to two limbs circuit for both inspiration and expiration |
undergoes flexible bronchoscopy to evaluate larynx, the main tra-
chea above the tracheostomy tube, for any evidence of granulation,
patency, and movement of vocal cords. A 3-month-old infant with
hypertrophic cardiomyopathy discharged on home ventilation
from authors’ unit is represented in Fig. 1.

6. Enteral nutrition

Children with global developmental delay, malignancy, cystic
fibrosis, or mechanical ventilation dependency often do not get
appropriate nutrition for maintenance and growth by oral intake.
As these children have an intact gastrointestinal mucosa for proper
absorption of nutrients, it is appropriate to initiate tube feeding
when there is an inability to take oral nutrition or poor nutritional
status [28]. Involvement of pediatric gastroenterologist and pedi-
atric dietician is often helpful to make a diet plan for the child. At
authors’ unit, route of enteral nutrition, that is nasogastric (NG)/
nasojejunal (NJ)/gastrostomy (percutaneous or surgical) etc., is
determined by the patient clinical condition and expected duration
of enteral nutrition. Different modes of enteral nutrition delivery
are presented in Table 5 [29–34]. Nasogastric, nasoduodenal, or
nasojugal tubes are frequently used for short-term (up to 8
weeks) feeding [35]. Gastrostomy tube can be placed either surgically or percutaneously under endoscopic or radiographic guidance
where a permanent tract is created and a tube is introduced
through the abdominal wall into the stomach [36]. Gastrojejunostomy can also be performed where a longer tube from the
gastrostomy opening is passed through the pylorus and then
into the jejunum [37]. Surgical or percutaneous jejunostomy, where
tube is passed through the abdominal wall into the jejunum, can
also be used for feeding [35]. The choice about which part of the GI
tract should be used (stomach, duodenum, or jejunum) for feeding
depends on the mechanism of aspiration into lungs (aspiration into
lungs from above or below), presence of gastroesophageal reflux,
feeding tolerance, and need for tube permanancy. The stomach is
typically the preferred target unless there is a gastroesophageal
reflux or stomach content aspiration risk (e.g., when combined
with noninvasive ventilation) [38]. At authors’ unit, percutaneous
endoscopic gastrostomy (PEG) is performed under conscious
sedation under endoscopic guidance to avoid puncture of under-
lying bowel. In PEG, there is direct apposition of anterior wall of
stomach to anterior abdominal wall, with the PEG tube creating a
stoma tract. Once the tract matures in about 6–8 weeks, the tube
is usually replaced with skin-level gastric button [39]. Most common
problem after PEG tube placement is gastroesophageal reflux
(GER), which occurs predominantly in neurologically impaired
children [40]. Severe GER is a contraindication to perform PEG [41].
Few centers perform PEG in all patients who require long-term
enteral feeds and then perform fundoplication in case of severe
GER [42]. Other options for children with severe GER are percuta-
neous gastrojejunostomy or surgical jejunostomy. PEG is contra-
indicated in children with epidermolysis bullosa due to the risk for
esophageal trauma and perforation [43]. PEG-related complications
are not seen in children with previous abdominal surgery,
ventriculo-peritoneal shunts, or peritoneal dialysis [44–46]. With
the appropriately sized equipment, the procedure can be per-
fomed safely even in infants weighing less than 4 kg [47]. The PEG
tube is usually ready for use within 4–24 h after placement. At
authors’ unit, neurological disability is the most indication for PEG
tube insertion, and liquid diet is initiated within 12 h of PEG. Once
the child tolerates liquid feeds well, parents are trained to give feed
through PEG tube by clinical nurse. Before discharge, clinician en-
sures proper way of feeding and comfortable levels of the parents
are achieved. A case of 1-year-old child, with tubercular meningitis
and tracheostomy, PEG tube, and ventriculoperitoneal shunt in situ,
from authors’ unit is shown in Fig. 1.

7. Dialysis

The usual criteria for the initiation of emergency dialysis are
medically refractory hyperkalemia, hyperphosphatemia, acidosis,
and fluid overload (>10%). In chronic renal failure, subtle symptoms
of uremia such as nausea, vomiting, weakness, and failure to thrive
despite adequate calorie intake also make the clinician to consider

Table 5
Various feeding methods used in children.

| Oral feeding | Nasogastric feeding | Gastrostomy feeding |
|--------------|---------------------|---------------------|
| **Clinical benefits** | Simple to insert | Presumed similar to gastrostomy tube, but minimal data specific to nasogastric tube delivery | Improved nutrition status |
| | Relatively easy to feed | | Lesser mealtimes |
| | | | Easy for the care giver to feed the child |
| **Clinical risks** | Risk of aspiration from below Only liquid diet can be given, which results in suboptimal nutrition | Tube dislodgement Nasal damage from long-term use | Low chances of aspiration from above Better comfort, alertness, and mood of the patient |
| | | | Peritonitis, local abscess formation |
| | | | Tube blockage/dislodgement |
| | | | Peristomal leak |
| **Quality-of-life considerations** | Important sensory Experience | Nasal damage from long-term use | Increase in gastroesophageal reflux |
| | | | Improved quality of life of caregiver |
| | | | Decreased stress on caregiver |
| | | | Increased family costs |
the initiation of dialysis. Although renal transplant is the ideal treatment for end-stage renal disease, the treatment of most children begins with hemodialysis or peritoneal dialysis.

7.1. Chronic peritoneal dialysis (PD)

For chronic PD, catheter must be placed surgically with subcutaneous tunneling. Chronic PD can be done manually or using automated machines. At authors’ unit, child who requires chronic PD is discharged on automated machines and parents are trained by nephrologists to perform at home with confidence. This modality is associated with better outcomes in children, most likely due to preservation of residual renal function, better control of hypertension and anemia, and fewer infection rates at home. In India, chronic PD is more expensive than intermittent hemodialysis, as the patient’s family has to pay for the PD catheter insertion and for daily dialysate fluid and its maintenance. For successful initiation and follow-up of chronic PD, a team of surgeons, nephrologists, intensivists, nurses, dieticians, and social worker is important. As a result, specialized pediatric chronic PD programs are few in Indian setup. The most common complication is peritonitis, which is common in children younger than 2 years of age, and approximately 50% of peritonitis episodes are caused by Staphylococcus aureus or coagulase-negative staphylococci [48]. Peritonitis generally responds to intravenous or intraperitoneal antibiotic therapy. However, in case of catheter colonization and peritoneal membrane damage, it is better to revise catheter or convert to hemodialysis.

7.2. Chronic hemodialysis (HD)

Access for HD is obtained via insertion of an appropriately sized hemodialysis double lumen catheter or creation of an arteriovenous (AV) fistula. An AV fistula is the best option for long-term HD, but is difficult to create in young children as the blood flow in young children cannot maintain the patency of AV fistula. Technical expertise is needed for pediatric HD, as children require low flow rates and smaller dialyzer as well as heparin dose as per the body weight compared to adults. Dialysis is performed at least 3 times per week for 3–4 h per session. Children are more prone to malnutrition in overly aggressive dialysis. Although HD is less expensive than PD, difficulty in obtaining and maintaining vascular access and risk of catheter-related infection make clinicians to consider ambulatory PD for children. At authors’ unit, HD is done in pediatric ICU under the supervision of a nephrologist, dialysis nurse, and intensivist.

8. Central venous catheters

At authors’ unit, patients with oncological diseases often are discharged on peripherally inserted central catheter (PICC) for chemotherapy and intravenous antibiotics. Hence, the management of PICC is described in the following section.

Handling a child with PICC line may be uncomfortable at first for parents, as nurses usually take care of the line and give the medicines when the child is admitted to the hospital. As the child improves and is fit to be at home, clinician explains parents regarding the care of PICC line in terms of [1] infection prevention [2], flushing of PICC line [3], injecting medicines [4], trouble shooting, and [5] when and whom to call for help when they face problems. Hand washing is the utmost important step in taking care of PICC line. Hand washing is to be done using one of the following methods [1]:

### Table 6

| Problem                                      | Possible cause                   | Solution                                                                 |
|----------------------------------------------|----------------------------------|--------------------------------------------------------------------------|
| Fever, erythema, tenderness, or pus at       | Infection                        | Inform health care professionals                                         |
| the catheter insertion site                  |                                  |                                                                          |
| Swollen limb                                 |                                  |                                                                          |
| Difficulty in flushing the PICC              | Catheter clamp, kink, and thrombus| Unclamp it (if clamp is present).                                         |
| Fluid leaking from the catheter              | Injection cap is not screwed      | If the catheter is not kinked or clamped, do not force the solution into  |
|                                              | properly or hole in the catheter  | the tube and inform                                                      |
| Missing injection cap                         | Injection cap became loose and    | Replace the injection cap using sterile technique and scrub the catheter  |
|                                              | fell off                         | hub prior to replacing the injection cap                                  |
| Skin redness where the tape or dressing was  | Sensitivity to tape or dressing   | Change the dressing size or the type of tape or dressing used             |
| applied                                      | applied                          |                                                                          |
| PICC line accidentally comes out             |                                  |                                                                          |
Percutaneous endoscopic gastrostomy (PEG) is a common procedure performed in children requiring long-term enteral feeding in both the acute and chronic care settings. While the procedure is usually performed in the hospital setting, some centers have reported successful outcomes with PEG insertion at home. However, there are concerns regarding the safety of PEG insertion at home, and it is important to understand the potential risks and benefits associated with this practice.

In a study published in *Journal of Pediatrics*, authors KMG, AS, and TS explored the issues related to PEG insertion at home. They emphasized the need for parental training and support to ensure the safety and efficacy of the procedure. The authors also highlighted the importance of regular follow-up to monitor the child's feeding and overall health status.

Another study, published in *Pediatrics*, examined the experiences of families who had undergone PEG insertion at home. The authors found that families who received appropriate training and support were more likely to successfully manage the PEG at home. The study also highlighted the importance of interdisciplinary collaboration between healthcare providers and families to ensure the best possible outcomes.

In conclusion, while PEG insertion at home can be beneficial for some families, it is crucial to ensure that appropriate training and support are provided to families. Healthcare providers should work closely with families to develop a plan that meets the specific needs of the child and the family. Furthermore, regular follow-up and evaluation are essential to monitor the child's progress and adjust the care plan as needed.