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Characteristics of children enrolled in Medicaid using respiratory equipment and supplies

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CHARACTERISTICS OF CHILDREN ENROLLED IN MEDICAID USING RESPIRATORY EQUIPMENT AND SUPPLIES

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DEDICATION

This thesis is dedicated to my parents, who have supported every dream of mine as their own. Thank you for teaching me, through example, that there is no substitute for hard work and perseverance.

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First, I am grateful to Dr. Jay Berry for his mentorship and expertise. Working with Dr. Berry this past year has been the most formative professional experience I have had. Dr. Berry's enthusiasm and passion for the patients he serves reminds me every day of the vital role physicians have in improving the health and wellbeing of society.

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CHARACTERISTICS OF CHILDREN ENROLLED IN MEDICAID USING RESPIRATORY EQUIPMENT AND SUPPLIES

DIPIKA GAUR

ABSTRACT

Background: Emerging evidence suggests that the population of children assisted with respiratory medical equipment and supplies (RMES) is increasing in size and is having a substantial impact on families, providers, and the health system. Little is known on a population level about children who use RMES to compensate for a deficit in the ability to breathe. This study addressed these gaps by assessing (1) the characteristics of children in Medicaid using RMES and (2) how the use of RMES influences healthcare utilization and spending across the care continuum.

Methods: A retrospective cohort analysis of 11,306 children using and 21,192 children not using RMES [propensity matched by age and complex chronic conditions (CCC)] who were age 0-to-21 years and continuously enrolled in Medicaid in 2013 from 10 states in the Truven Health Medicaid MarketScan Database. RMES use at home (not counting acute use in a clinic, emergency department, or hospital) was identified with Healthcare Common Procedure Coding System (HCPCS), billed by medical supply companies, and International Classification of Diseases (ICD9) codes, billed by clinicians and hospitals. RMES included oxygen, suctioning, apnea monitor, CPAP/BiPAP, tracheostomy, ventilator, cough assist, and vest. We regressed RMES use on total annual per member per year (PMPY) Medicaid payments, adjusting for enrollment reason, gender, age, race/ethnicity, and number of chronic conditions.

Results: Of children using RMES at home, 5% were identified with ICD9 only, 80% with HCPCS only, and 15% with ICD9 and HCPCS. Most (87%) children using RMES had a chronic condition (of any complexity); 71% had a complex chronic condition. Neuromuscular (32%) was the most common CCC. RMES usage among children included oxygen (47%), suctioning (28%), apnea monitor (23%), CPAP/BiPAP (22%), tracheostomy (17%), ventilator (8%), cough assist (5%), and vest (4%). PMPY payments in propensity-matched children using vs. not using RMES were $45,892 vs. $15,036, $p<0.001$. In adjusted analysis, payment increased significantly ($p<.001$) with use of CPAP/BiPAP (+$1,117), oxygen (+$3,525), cough assist (+$6,342), suctioning (+$8,569), tracheostomy (+$11,977), vest (+$11,999), apnea monitor (+$13,747), and ventilator (+$32,323). Of children using RMES, most payments were for hospitalization (57%), specialty care (24%), and medications (6%); <3% was for RMES or home nursing.

Conclusion: RMES use can identify additional projected healthcare costs in children beyond consideration of chronic diagnoses. Because most of the cost of using RMES is due to inpatient and specialty care rather than the equipment itself, RMES may indicate – broadly - medical fragility and increased healthcare needs. Population health initiatives of children with medical complexity may benefit from consideration of RMES use in risk assessment for healthcare cost.

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LIST OF ABBREVIATIONS

BiPAP ..... Bilevel positive airway pressure

BOE..... Basis of eligibility

CCC ..... Complex chronic condition

CCI..... Chronic Condition Indicator system

CPAP ..... Continuous positive airway pressure

DME..... Durable medical equipment

HCPCS..... Healthcare Common Procedure Coding System

HFCWO ..... High frequency chest wall oscillation

HH..... Home healthcare

ICD-9 ..... International Classification of Diseases, Ninth Revision

IQR..... Interquartile range

MH/SA..... Mental health/substance abuse

MTA..... Medical technology assistance

NPPV ..... Noninvasive positive pressure ventilation

PCP ..... Primary care physician

PMPY..... Per member per year

USOTA ..... United States Office of Technology Assessment

INTRODUCTION

Medical Technology Assistance

Individuals who are assisted by medical technology require the use of a medical device to compensate for the total loss or reduction of vital body function. There is significant variation in the patient populations who require medical technology assistance (MTA), as well as in the types of technologies utilized.[1,2] (Figure 1) For example, children with diabetes mellitus type 1 who require regular administration of insulin to compensate for insufficient production by the body can utilize insulin pumps.[3] Patients with acute or chronic renal insufficiency may require dialysis to compensate for lost kidney function. How long a patient has to remain on dialysis treatments is highly individualized and depends on the severity of his or her disease.[4]

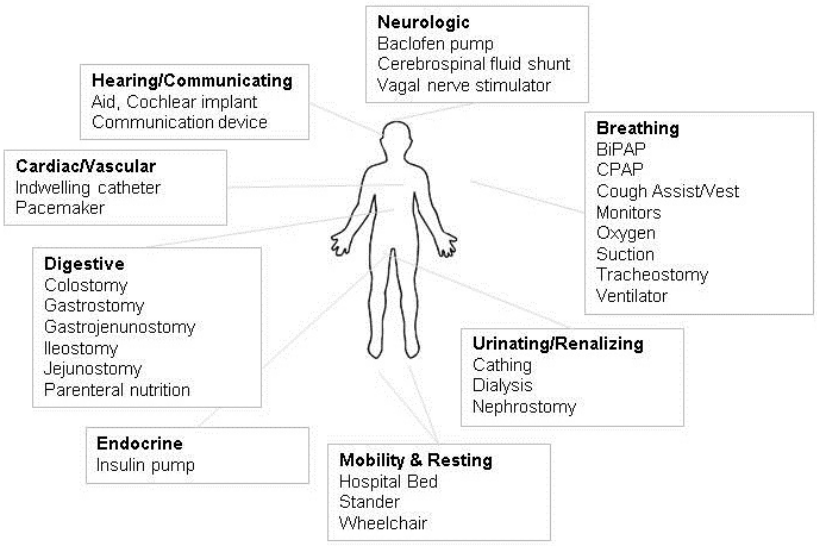

Figure 1: Technologies Utilized By Patients with Various Medical Conditions

Medical Technology Assistance Among Children

Among individuals with MTA, children represent a growing, medically complex patient population with unique health care needs and various underlying conditions. While many different definitions have been proposed for children with MTA, there is no standardized terminology and definition in use for this population. This lack of standardized terminology is a barrier to locating, sharing, and aggregating data to improve patient care and outcomes. One well known and often cited definition[5-7] comes from the United States Office of Technology Assessment (USOTA). In 1987, the USOTA defined the technology-dependent child as one who requires "a medical device to compensate for the loss of a vital body function and substantial and ongoing nursing care to avert death or further disability."[8] Notably, this long-standing definition does not specify the setting of care delivery, qualifications of the care-giver, or duration of medical device utilization. These aspects of care for children with MTA have remained individualized for each patient, depending on the severity of his or her condition and dynamics of the child's social and home environments.

Although the USOTA refers to these children as technology-dependent children, other frequently used terms include: children with MTA, children with assistive technology, and technology-assisted children. In this paper, children who require the use of a medical device to compensate for the total loss or reduction of vital body function will be referred to as children with MTA. This terminology employs "person-first" language, emphasizing that a child's medical condition is one part of his or her identity.[9] Unlike the definition from the USOTA, the one used in this paper does not specify

nursing care requirements, as there is significant variation in each child's needs. Additionally, physicians who care for children with MTA have disagreed about how much emphasis to place on nursing care and whether to include nursing care in the definition of this patient population[10].

Children with MTA include, but are not limited to, children who require one or more of the following: tracheostomy, respirator, ventilator, supplementary oxygen, suctioning, gastrostomy, jejunal or nasogastric feeding tubes, urostomy, urethral catheterization, central venous access, or dialysis[1]. As demonstrated by this range of technologies and procedures, patients with a variety of clinical diagnoses require technology assistance as part of their long-term care needs. (Table 1)

Table 1: List of Affected Organ Systems and Related Clinical Diagnoses That May Require MTA[1]

Organ System	Diagnoses
Neurologic	Congenital anomalies of the central nervous system; spastic quadriplegia; neuromuscular disorders; spinal cord injuries; seizure disorders; central nervous system infections; hypoxic and other encephalopathies
Multisystem	Inborn errors of metabolism; chromosomal anomalies; acquired immunodeficiency syndrome
Cancer-hematologic	Leukemia; solid organ malignancies; thalassemia; sickle cell anemia; hemophilia
Cardio-respiratory	Bronchopulmonary dysplasia; asthma; chronic lung disorders; congenital heart disease
Gastrointestinal-metabolic	Inflammatory bowel disease; gastroesophageal reflux; dumping syndrome; malabsorption; necrotizing enterocolitis; congenital anomalies of the gastrointestinal tract
Renal-genitourinary	Chronic renal failure; congenital genitourinary anomalies; glomerulonephritis
Musculoskeletal	Arthritis; osteomyelitis; osteogenesis imperfecta; Ehlers-Danlos syndrome
Immunologic	Agammaglobulinemia; hypogammaglobulinemia

Advancements in medical technology have reduced patient mortality and contributed significantly to the growing population size of children with MTA.[11] Technological improvements have also allowed many of these children, who previously required continuous inpatient care, to successfully transition from hospitals and long-term care facilities to home-based care.[12] There are numerous emotional and social benefits to living at home for patients and their families. In addition, home-based care may decrease healthcare costs and mitigate other financial stressors associated with lengthy, complex hospitalizations. Previous studies show that children with MTA have long hospital stays, multiple providers involved in their care, high inpatient resource utilization, and insufficient care coordination to meet their complex health needs.[11,13] Hospital discharge of these complex patients is often prolonged because of non-medical reasons[14-16], including delayed public funding approval and availability of home nursing care. As the number of children with MTA who transition from hospital to home-based care increases, research on the impact of changes in healthcare delivery on resource utilization and costs is imperative.

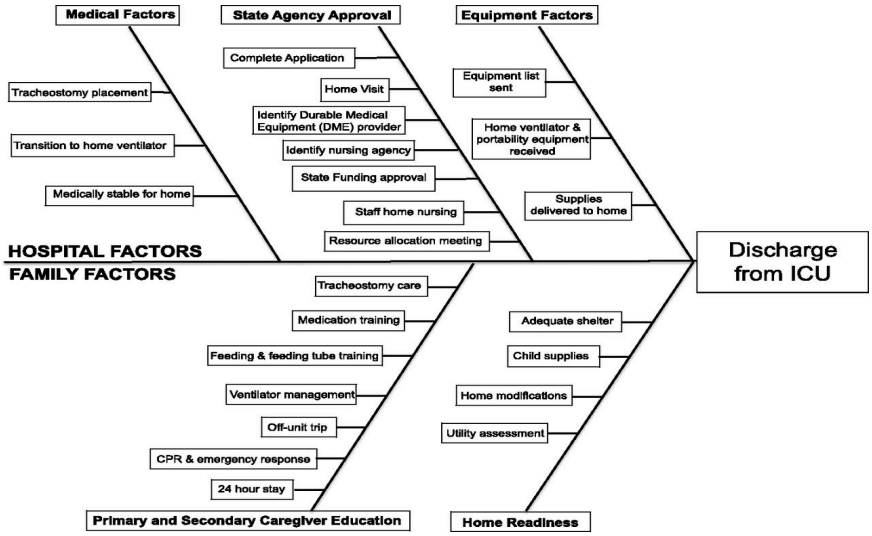

Figure 2: Factors Delaying Discharge from ICU with Respiratory Technology [16]

Children with Respiratory Technology Assistance

Included in the population of children with MTA are patients with respiratory system morbidities. Children with respiratory TA are those who require respiratory medical equipment and supplies (RMES) to maintain optimal pulmonary function. The respiratory system is comprised of multiple organs and structures that can be anatomically divided into two portions – the upper and lower respiratory tracts. The upper respiratory tract includes the nose, pharynx, and larynx. The lower respiratory tract includes the trachea, left and right bronchi, bronchioles, and lungs. (Figure 2) Within the lungs, the smallest units of respiration are the alveoli – tiny, sac-like structures that serve as the site of gaseous exchange between the lungs and blood. Collectively, millions of alveoli facilitate the transport of oxygen from air into the blood and removal of carbon dioxide from blood into the air. (Figure 3) This gaseous exchange of oxygen and carbon dioxide is the main function of the respiratory system.

RMES are utilized by patients when respiratory function is compromised due to a variety of underlying conditions and causes. Impairment of respiratory function can be intermittent or chronic, and the technologies described in the next subsection are utilized by patients to supplement or take over the body's respiratory efforts.

Respiratory Medical Equipment and Supplies

Oxygen

Patients with a variety of medical conditions, such as chronic obstructive pulmonary disease (COPD), bronchopulmonary dysplasia, or heart failure, may require oxygen therapy, which is also known as supplemental oxygen. Oxygen therapy involves giving oxygen to an individual via face mask or nasal tubes to increase blood oxygen levels and counter the hazardous effects of low blood oxygen concentration. Oxygen therapy can be administered over short or long periods of time in multiple healthcare settings (i.e. hospital, rehabilitation facility, home, school, etc.) Portable tanks and oxygen concentrators allow patients to receive oxygen therapy while moving around. In portable tanks, Oxygen is stored as a gas or liquid form and can be re-filled. Oxygen concentrators are devices which concentrate oxygen from a gaseous supply – typically ambient air– for immediate use by the patient.

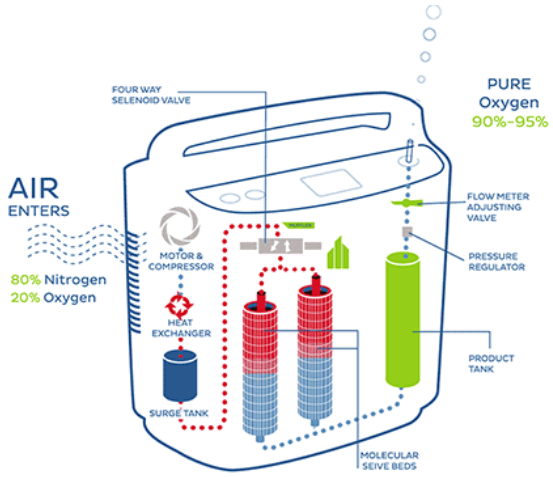

Figure 3: Components of a Portable Oxygen Concentrator. Source: The Oxygen Concentrator Store. Downloaded from: http://www.oxygenconcentratorstore.com

Noninvasive positive pressure ventilation

Noninvasive positive pressure ventilation (NPPV) refers to the administration of positive pressure ventilatory support without using an invasive artificial airway (i.e. a tracheostomy tube). NPPV is indicated for multiple conditions, including obstructive sleep apnea, chronic neuromuscular disease, facial and/or pharyngeal malformations and dysfunctions, and respiratory disease.[17] Over the past 20 years, NPPV has become an integral management tool for acute and chronic respiratory failure in hospital and home-based patient care.[18] In NPPV, air pressure is administered into an individual's airways, through a face mask, nasal mask, or nasal plugs, to prevent respiratory distress (i.e. airway collapse) and improve breathing. NPPV can be continuous (CPAP), bi-level (BiPAP), or automatically adjusting (APAP). CPAP machines constantly administer air at a single level of air pressure. Unlike CPAP, BiPAP machines cyclically deliver air at two distinct pressures – a higher pressure during inhalation and a lower pressure during

exhalation. Like CPAP, APAP provides continuous provision of air pressure into the airways. However, APAP machines use built-in technology to recognize changes in an individual's breathing and adjust the air pressure being administered to an appropriate level.

Figure 4: Administration of Noninvasive Positive Airway Pressure. Source: PruebasBMA. Downloaded from https://en.wikipedia.org/wiki/Positive_airway_pressure

Cough Assist

Respiratory problems that impair breathing also impact an individual's ability to cough. When an individual is unable to cough regularly, the lungs and airways retain excess secretions, increasing the risk of infection, inflammation, and eventually, respiratory failure. Cough assist devices help patients with loosening and clearing secretions by providing high frequency oscillatory vibrations while gradually applying a positive pressure to the airway, then rapidly shifting to a negative pressure. The oscillatory vibrations assist in loosening and mobilizing the secretions and the rapid shift in pressure produces a high expiratory flow rate from the lungs, promoting the clearance of secretions. A cough assist device can be used with either a facemask, mouthpiece, or with an adapter to a patient's endotracheal or tracheostomy tube. Cough assist devices

can be used by adult and pediatric patients for secretion clearance and/or inability to cough in various healthcare settings (i.e. hospitals, institutional environments, or home).

Tracheostomy

A tracheotomy is a surgical procedure in which a surgeon makes an incision through the skin of the neck into the trachea and creates an opening to accommodate a tracheostomy tube. (Figure 4) Once the tracheostomy tube is inserted into this opening, it serves as a passageway for patients to breathe and for removal of secretions. A patient with a tracheostomy tube breathes through the tube, instead of using his or her nose and mouth. Although the terms are often, incorrectly used interchangeably[17,19], tracheotomy refers to the surgical procedure and tracheostomy refers to the hole-like opening.

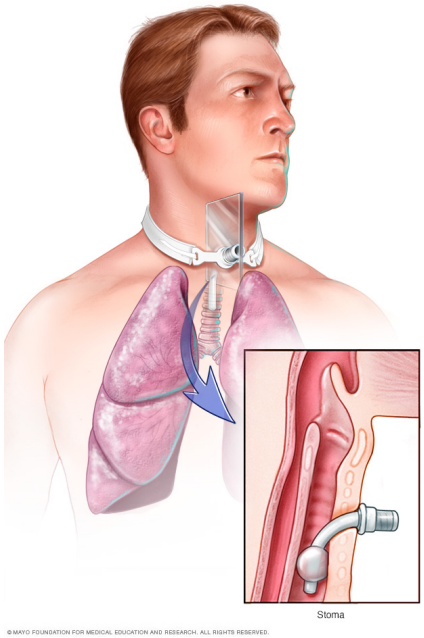

Figure 5: Tracheostomy. Source: Mayo Clinic. Downloaded from: http://www.mayoclinic.org/tests-procedures/tracheostomy/home/

Tracheostomy tubes are indicated for children who cannot control their breathing, patients with upper airway obstruction, and patients supported by long-term mechanical ventilation. While the specifics of tracheostomy care are individualized to each patient's needs (i.e. whether the patient uses a cuffed tracheostomy tube), standards of care in hospitals and other healthcare facilities include the following: 24-hour access to a provider trained in addressing tracheostomy complications, routine visits from respiratory therapists, attention to humidification and suctioning (removal of secretions) needs, and ready availability of replacement tracheostomy tubes of the appropriate size.[17,20] Once a child with a tracheostomy tube is deemed medically stable by his or her physician, the patient can transition from hospital to home-based care, given the following: completion of caregiver education, establishment of home nursing and respite care plan, availability of durable medical equipment and supplies, and lack of catastrophic financial concerns. Whether in an institutional or home environment, children who utilize tracheostomy tubes require regular support from trained caregivers.[20]

Suction

A tracheostomy tube bypasses the upper airways, which warm, moisten, and clean the air we breathe. In the absence of these protective measures, the air that travels through the tracheostomy tube is cooler, drier, and less clean. In response, the airways produce more mucus. Suctioning clears mucus from the tracheostomy tube, promoting adequate breathing and preventing contamination of the tube and potential infection. Notably,

suctioning should be conducted as recommended by the patient's health care team, but suctioning too frequently can lead to increased production of mucus by the body.

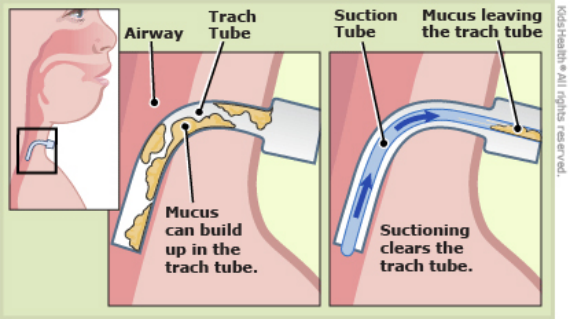

Figure 6: Suctioning a Tracheostomy. Source: Kids Health. Downloaded from https://kidshealth.org/

High Frequency Chest Wall Oscillation (HFCWO) Assistance Vests

HFCWO is a routine part of care for many patients who require assistance with airway clearance. HFCWO technology consists of an inflatable vest and air pulse generator that is connected to the vest by hoses. (Figure 7) The inflatable vest is worn by the patient, and the air pulse generator mimics manual chest physical therapy by vibrating at variable frequencies and intensities, as set by the patient's caregiver. The generator sends air into the vest through the hoses, causing the vest to inflate and deflate quickly. The rapid, cyclic inflation and deflation have a similar effect as that of manual clapping on a patient's chest. The vibrations dislodge mucus from the lining of the airways and facilitate movement of mucus up from smaller airways into larger airways. Treatment sessions with HFCWO vests commonly last 30 minutes and incorporate regular breaks to facilitate coughing and respiration, as needed.[21] HFCWO vests are widely used for

treatment of various respiratory diseases in the United States, and are considered part of standard care procedures for treatment of cystic fibrosis.[21,22]

Figure 7: Child Using HFCWO Vest. Source: Bronchiectasis Toolbox. Downloaded from http://bronchiectasis.com.au/

Ventilator

Mechanical ventilators assist patients with breathing by delivering gas to the airways through a set of tubes known as the patient circuit. Ventilators work by mimicking the breathing patterns of adults and children, and the machines are programmed to deliver gas at a specific number of breaths per minute, as set by a health professional or caregiver. In invasive ventilation, the circuit connects the ventilator to an endotracheal tube or a tracheostomy tube. In noninvasive ventilation, the circuit connects the ventilator to nasal prongs, a nasal mask, or a facial mask. Mechanical ventilators can be used by patients in a variety of healthcare settings. Some patients require mechanical ventilation for short periods of time (i.e. when recovering from an injury), while others

may require long-term ventilation support, depending on their diagnosis and treatment plan.

Apnea Monitor

Apnea monitors are devices that continuously measure an individual's chest movements and heart rate for any pauses in breathing (apnea) or slowing of the heart rate below age-appropriate levels (bradycardia). These monitors are primarily used to detect the cessation of breathing in infants and adults who are at risk for respiratory failure and alert the individual's caregiver to their worsening condition. During prolonged pauses in respiration, the body's oxygen concentration decreases, which can lead to irreversible brain damage or death. Children may require apnea monitoring in the hospital and/or home for a variety of reasons, including: prematurity, chronic lung disease, neurologic or metabolic disorders affecting respiratory control, presence of an anatomic abnormality or use of a tracheostomy that increases likelihood of airway compromise. While the specific components of an apnea monitor may vary by brand, they are generally composed of sensors that attach to the skin and obtain information on physiological parameters like heart rate. These sensors are connected to a monitor that analyzes this information and determines whether or not apnea is occurring. If apnea is detected, the monitor will sound an alarm to alert the child's or adult's caregiver.

SPECIFIC AIMS

The specific aims of this study are (1) to assess the prevalence of children enrolled in Medicaid using respiratory durable medical equipment (2) to assess how the use of respiratory medical equipment and supplies (RMES) influences healthcare utilization and spending across the care continuum.

METHODS

Study Design and Setting

This is a retrospective cohort study of healthcare claims data contained in the Truven MarketScan Medicaid Multistate Database from 2012 to 2014. The Truven database contains information on inpatient admissions, inpatient services, outpatient services, prescription drug claims, long-term care, and other medical care from ten state contributors. The Truven database is de-identified and complies with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). A review of this study by the Boston Children's Hospital Institutional Review Board was waived, because the study did not collect, use, or transmit any individually identifiable data.

Study Participants

Study participants were children ages 0-18 who (1) used RMES in 2013 and (2) were continuously enrolled in Medicaid for 11 to 12 months before their first RMES healthcare claim (if child was age 11 months or older in January 2013), as well as 12 months after the first claim (for all ages). Two methods were used to identify RMES

usage among children: (1) International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes and (2) the Healthcare Common Procedure Coding System (HCPCS).

Respiratory Medical Equipment and Supply ICD-9-CM Codes

ICD-9-CM codes correspond to specific diagnoses and procedures that are part of medical care provided to patients. These codes are utilized for diagnostic, billing, and reporting purposes by clinical professionals and healthcare administrators. For example, ICD-9-CM codes are regularly utilized by administrators to indicate diagnoses and procedures for a patient interaction when submitting reimbursement claims to payers, such as insurance companies. In this study, the ICD-9-CM code categories used to identify RMES usage among children include: tracheostomy, mechanical ventilation, suction, and oxygen. (Table 2)

Respiratory Medical Equipment and Supply HCPCS

The Centers for Medicare and Medicaid Services' HCPCS is a set of codes that corresponds to specific items and procedures provided to patients as part of medical care, including non-physician services and equipment, like ambulance services and durable medical equipment. For example, companies that supply durable medical equipment to patients utilize HCPCS when sending billing claims to payers. In this study, HCPCS codes were categorized into the following groups to identify RMES usage among children: apnea monitor, cough assist, non-invasive positive pressure, oxygen, suction, tracheostomy, mechanical ventilator, and vest. (Table 2)

Table 2: ICD9 and HCPCS Codes Utilized For Specific RMES

System	Code	Description
Tracheostomy		
ICD9	31.2	Permanent tracheostomy
	31.21	Mediastinal tracheostomy
	31.29	Other permanent tracheostomy
	31.41	Tracheoscopy through artificial stoma
	31.74	Revision of tracheostomy
	33.21	Bronchoscopy through artificial stoma
	96.55	Tracheostomy toilette
	97.23	Replacement of tracheostomy tube
	519.xx	Tracheostomy complications
	V44.0	Artificial opening status - tracheostomy
	V55.0	Attention to artificial openings – tracheostomy
HCPCS	A7526	Tracheostomy tube collar/holder, each
	A7520	Tracheostomy/laryngectomy tube, non-cuffed, polyvinylchloride (pvc), silicone or equal
	A7525	Tracheostomy mask
	A4629	Tracheostomy care kit for established tracheostomy
	A7521	Tracheostomy/laryngectomy tube, cuffed, polyvinylchloride (pvc), silicone or equal
	L8501	Tracheostomy speaking valve
	A7507	Filter holder and integrated filter, tracheostomy heat and moisture exchange system
	S8189	Tracheostomy supply, not otherwise classified
	A4623	Tracheostomy, inner cannula
	A7509	Filter holder, housing, and adhesive, tracheostomy heat and moisture exchange system
	A4625	Tracheostomy care kit for new tracheostomy
	A7527	Tracheostomy/laryngectomy tube plug/stop
	A7504	Filter for use in a tracheostomy heat and moisture exchange system
	A4626	Tracheostomy cleaning brush
	A7503	Filter holder or filter cap, reusable, tracheostomy heat and moisture exchange system
	A7522	Tracheostomy/laryngectomy tube, stainless steel or equal (sterilizable and reusable)
	A7523	Tracheostomy shower protector
Oxygen		
ICD9	V46.2	Dependence on supplemental oxygen
HCPCS	E1390	Oxygen concentrator, single delivery port, capable of delivering 85 percent or greater oxygen concentration at the prescribed flow rate
	E0431	Portable gaseous oxygen system, rental; includes portable container, regulator, flowmeter, humidifier, cannula or mask, and tubing
	E0445	Oximeter device for measuring blood oxygen levels non-invasively
	A4606	Oxygen probe for use with oximeter device, replacement
	E0565	Compressor, air power source for equipment which is not self-contained or cylinder driven

	E0424	Stationary compressed gaseous oxygen system, rental; includes container, contents, regulator, flowmeter, humidifier, nebulizer, cannula or mask, and tubing
	K0738	Portable gaseous oxygen system, rental; home compressor used to fill portable oxygen cylinders; includes portable containers, regulator, flowmeter, humidifier, cannula or mask, and tubing
	E0441	Oxygen contents, gaseous (for use with owned gaseous stationary systems or when both a stationary and portable gaseous system are owned), 1 month's supply = 1 unit
	E0439	Stationary liquid oxygen system, rental; includes container, contents, regulator, flowmeter, humidifier, nebulizer, cannula or mask, and tubing
	E0550	Humidifier, durable for extensive supplemental humidification during IPPB treatments or oxygen delivery
	E0434	Portable liquid oxygen system, rental; includes portable container, supply reservoir, humidifier, flowmeter, refill adaptor, contents gauge, cannula or mask, and tubing
	E0443	Portable oxygen contents, gaseous (for use only with portable gaseous systems when no stationary gas or liquid system is used), 1 month's supply = 1 unit
	E1392	Portable oxygen concentrator, rental
	E1353	Regulator
	E0560	Humidifier, durable for supplemental humidification during IPPB treatment or oxygen delivery
	E0442	Oxygen contents, liquid (for use with owned liquid stationary systems or when both a stationary and portable liquid system are owned), 1 month's supply = 1 unit
	E0430	Portable gaseous oxygen system, purchase; includes regulator, flowmeter, humidifier, cannula or mas, and tubing
	E0444	Portable oxygen contents, liquid (for use only with portable liquid systems when no stationary gas or liquid system is used), 1 month's supply = 1 unit
Ventilator		
ICD9	34.85	Implantation of diaphragmatic pacemaker
	V46.1	Dependence on respirator (ventilator)
HCPCS	A4483	Moisture exchanger, disposable, for use with invasive mechanical ventilation
	E0463	Pressure support ventilator with volume control mode, may include pressure control mode, used with invasive interface (e.g. tracheostomy tube)
	E0464	Pressure support ventilator with volume control mode, may include pressure control mode, used with non-invasive interface (e.g. mask)
	E0450	Volume control ventilator, without pressure support mode, may include pressure control mode, used with invasive interface (e.g. tracheostomy tube)
	A4611	Battery, heavy duty; replacement for patient owned ventilator
	A4613	Battery charger; replacement for patient-owned ventilator
	E0461	Volume control ventilator, without pressure support mode, may include pressure control mode, used with a non-invasive interface
Suction		
ICD 9	V46.0	Aspirator
HCPCS	A7002	Tubing, used with suction pump, each
	A7000	Canister, disposable, used with suction pump, each
	A4624	Tracheal suction catheter, any type other than closed system, each
	E0600	Respiratory suction pump, home model, portable or stationary, electric
	A4605	Tracheal suction catheter, closed system, each

	A7001	Canister, non-disposable, used with suction pump, each
Vest		
HCPCS	E0483	High frequency chest wall oscillation air-pulse generator system, (includes hoses and vest), each
	E0480	Percussor, electric or pneumatic, home model
	E0481	Intrapulmonary percussive ventilation system and related accessories
	A7025	High frequency chest wall oscillation system vest, replacement for use with patient owned equipment, each
Oral Airway		
HCPCS	E0486	Oral device/appliance used to reduce upper airway collapsibility, adjustable or non-adjustable, custom fabricated, includes fitting and adjustment
CPAP/BiPAP		
HCPCS	A7035	Headgear used with positive airway pressure device
	A7038	Filter, disposable, used with positive airway pressure device
	E0601	Continuous airway pressure (CPAP) device
	A7037	Tubing used with positive airway pressure device
	E0562	Humidifier, heated, used with positive airway pressure device
	A7030	Full face mask used with positive airway pressure device, each
	A7034	Nasal interface (mask or cannula type) used with positive airway pressure device, replacement, each
	A7039	Filter, non-disposable, used with positive airway pressure device
	A7046	Water chamber for humidifier, used with positive airway pressure device, replacement, each
	A4604	Tubing with integrated heating element for use with positive airway pressure device
	E0561	Humidifier, non-heated, used with positive airway pressure device
	A7036	Chinstrap used with positive airway pressure device
	A7027	Combination oral/nasal mask, used with continuous positive airway pressure device, each
	A7044	Oral interface used with positive airway pressure device, each
Cough Assist		
HCPCS	E0482	Cough stimulating device, alternating positive and negative airway pressure
	E0471	Respiratory assist device, bi-level pressure capability, with back-up rate feature, used with noninvasive interface, e.g., nasal or facial mask (intermittent assist device with continuous positive airway pressure device)
	E0470	Respiratory assist device, bi-level pressure capability, without back-up rate feature, used with noninvasive interface, e.g., nasal or facial mask (intermittent assist device with continuous positive airway pressure device)
	E0484	Oscillatory positive expiratory pressure device, non-electric, any type, each
	E0472	Respiratory assist device, bi-level pressure capability, with backup rate feature, used with invasive interface, e.g., tracheostomy tube (intermittent assist device with continuous positive airway pressure device)
Apnea Monitor		
HCPCS	E0619	Apnea monitor, with recording feature
	A4556	Electrodes, (e.g. apnea monitor), per pair
	A4557	Lead wires, (e.g. apnea monitor), per pair
	E0618	Apnea monitor, without recording feature

Main Outcome Measures

The main outcomes were total healthcare expenditure and utilization of services over a 12-month period. In order to confirm inclusion of a complete 12-month period of RMES usage, outcomes were evaluated during the 12 months following either (1) the first RMES claim in 2013 for children without a claim in the preceding 12 months, including in 2012; or (2) January, 1, 2013 for children with a RMES claim in 2012. Outcomes were assessed across all services and by individual health services. These health services include dental, durable medical equipment, emergency department, home health, inpatient, primary care, specialty care, and therapy (i.e. physical, occupational, and other outpatient therapies). Expenditure was described for each health service as the gross payment. Utilization was reported as the proportion of patients using each health service and the frequency of claims for the respective service.

Demographic and Clinical Characteristics of the Children

The demographic characteristics of interest were age, gender, race/ethnicity, basis of eligibility for Medicaid, and provider payment systems (i.e. fee-for-service and/or managed care plans). Each child's age, gender, and race/ethnicity were recorded at the time of their first RMES claim in 2013. Clinical characteristics of interest were the number and type of chronic conditions, the number and identity of body systems affected, and medical technology assistance. Data for these clinical characteristics were measured for all healthcare encounters up to 12 months before and after the date of each child's first RMES claim in 2013.

The Agency for Healthcare Research and Quality's Chronic Condition Indicator (CCI) system was utilized to identify the number and type of chronic conditions. The CCI system classifies the approximately 14,000 current ICD-9-CM diagnosis codes into chronic and non-chronic conditions. CCI also classifies ICD-9-CM codes into one of 18 body systems categories, providing further information on the number and identity of body systems that are affected by a chronic condition. A chronic condition is defined by the CCI as a condition that lasts 12 months or longer and fulfills one or both of the following criteria: (1) limits self-care, independent living, and social interactions; and/or (2) requires ongoing intervention with medical products, services, and special equipment. In this study, hospitalized children with a chronic condition were further categorized for presence of a complex chronic condition (CCC), according to an ICD-9-CM diagnosis classification system. A CCC refers to any medical condition that can be reasonably expected to last at least 12 months (unless death intervenes) and to involve either several different organ systems or 1 system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center.[23,24] Hospitalized children assisted by medical technologies were identified by ICD-9-CM codes for the utilization of a medical device to manage and treat a chronic illness or to maintain basic body functions necessary for sustaining life.

Statistical Analysis

Children who did use and did not use RMES were propensity matched by age and CCC. In bivariable analysis, we compared healthcare spending across the children's

categorization of use of respiratory equipment and supplies using Wilcoxon Rank Sum tests.[25] To assess these relationships in multivariable analysis, we derived a linear regression model - with total healthcare spending as the outcome - that included fixed effects for the children's demographic and clinical characteristics. We also derived a logistic regression model – with hospitalization as the outcome – using the same fixed effects. All statistical analyses were performed using SAS v.9.4 (SAS Institute, Cary, NC), and the threshold for statistical significance was set at $p<0.05$.

Limitations

The Truven database contains a variety of outpatient health care encounters aggregated into an "other" category; most of the encounters in this category appear to be for specialty visits. The generalizability of the Truven database remains unknown, given Truven's inability to disclose the states in their database and the absence of a nationally representative, validated database of children with Medicaid.

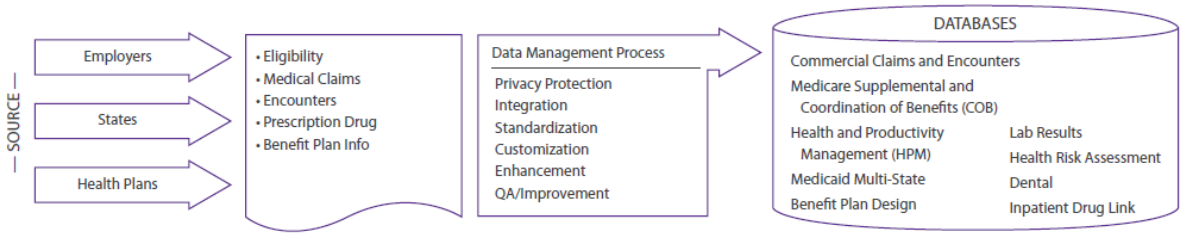

Figure 8: Truven MarketScan Research Databases. Source: Truven Health Analytics, "Health Research Data For The Real World: MarketScan Databases"

RESULTS

Of all children who utilized RMES at home in 2013, 4.7% were identified using only ICD9 codes, 79.8% were identified using only HCPCS codes, and 15.5% were identified using both ICD9 and HCPCS codes.

70.5% of these children had a CCC, with neuromuscular (31.8%), cardiovascular (27.2%), and respiratory (25.2%) being the most common CCCs. 31.5% of children with CCC had six or more body systems affected by their condition. The most common RMES used were supplementary oxygen (47.2%), suctioning (27.9%), apnea monitors (22.4%), CPAP/BiPAP (21.9%), and tracheostomies (16.5%). Other RMES utilized include ventilators (7.8%), cough assist (4.8%), and HFCWO assistance vests (4.1%).

Data presented in Tables 3-7 separate study participants into three categories: (1) all children who utilized RMES in 2013 (2) children who did not utilize RMES in 2012, but did utilize RMES in 2013 and (2) children who utilized RMES in 2012 and 2013. These categories are respectively referred to as overall, incident, and prevalent in Tables 3-7. Results shared in this section and the discussion focuses on all children who utilized RMES in 2013.

Table 3: Demographic and Clinical Characteristics of Children Assisted with RMES

		Overall	Cohort Type		P
			Incident	Prevalent	
# and % of Enrollees		12861	7877 (61.3)	4984 (38.8)	
	ICD9 Only	608 (4.7)	441 (5.6)	167 (3.4)	<.001
	HCPCS Only	10261 (79.8)	6953 (88.3)	3308 (66.4)	
	Both ICD9 and HCPCS	1992 (15.5)	483 (6.1)	1509 (30.3)	
Age: Median [IQR]	**0**	3264 (25.4)	3264 (41.4)		<.001
	1-4	2925 (22.7)	1522 (19.3)	1403 (28.2)	
	5-12	3610 (28.1)	1712 (21.7)	1898 (38.1)	
	13-17	1903 (14.8)	929 (11.8)	974 (19.5)	
	18+	1159 (9)	450 (5.7)	709 (14.2)	
BOE	**Blind/Disabled Individual**	5084 (39.5)	2111 (26.8)	2973 (59.7)	<.001
	Other	7777 (60.5)	5766 (73.2)	2011 (40.3)	
Race	**White**	5732 (44.6)	3720 (47.2)	2012 (40.4)	<.001
	Black	2810 (21.8)	1870 (23.7)	940 (18.9)	
	Hispanic	928 (7.2)	694 (8.8)	234 (4.7)	
	Other	3391 (26.4)	1593 (20.2)	1798 (36.1)	
Gender	**Male**	7115 (55.3)	4303 (54.6)	2812 (56.4)	0.046
	Female	5746 (44.7)	3574 (45.4)	2172 (43.6)	
Managed Care	**Fee-for-service**	5586 (43.4)	2698 (34.3)	2888 (57.9)	
	Capitated	7275 (56.6)	5179 (65.7)	2096 (42.1)	
CCCs v.2.0	**Neuromuscular**	4084 (31.8)	1471 (18.7)	2613 (52.4)	<.001
	CVD	3492 (27.2)	1845 (23.4)	1647 (33)	<.001
	Respiratory	3246 (25.2)	1187 (15.1)	2059 (41.3)	<.001
	Renal	828 (6.4)	326 (4.1)	502 (10.1)	<.001
	GI	3991 (31)	1564 (19.9)	2427 (48.7)	<.001

	Hematology and immunodeficiency	717 (5.6)	344 (4.4)	373 (7.5)	<.001
	Metabolic	1449 (11.3)	701 (8.9)	748 (15)	<.001
	Congenital or genetic defect	3001 (23.3)	1096 (13.9)	1905 (38.2)	<.001
	Malignancy	2463 (19.2)	1107 (14.1)	1356 (27.2)	<.001
	Neonatal	1992 (15.5)	1174 (14.9)	818 (16.4)	0.021
	Tech Depend	4247 (33)	1520 (19.3)	2727 (54.7)	<.001
	Transplant	99 (0.8)	47 (0.6)	52 (1)	0.005
	Any	9068 (70.5)	4833 (61.4)	4235 (85)	<.001
Technology Dependence (from CCCs v.2.0)	**Respiratory**	1980 (15.4)	404 (5.1)	1576 (31.6)	
	GI	3801 (29.6)	1453 (18.4)	2348 (47.1)	
	CV	525 (4.1)	196 (2.5)	329 (6.6)	
	Neuromuscular	519 (4)	191 (2.4)	328 (6.6)	
	Other	4854 (37.7)	2506 (31.8)	2348 (47.1)	
	Renal	201 (1.6)	79 (1)	122 (2.4)	
N CCI Body Systems	**0**	981 (7.6)	890 (11.3)	91 (1.8)	<.001
	1	1685 (13.1)	1476 (18.7)	209 (4.2)	
	2	1672 (13)	1349 (17.1)	323 (6.5)	
	3	1600 (12.4)	1164 (14.8)	436 (8.7)	
	4	1478 (11.5)	894 (11.3)	584 (11.7)	
	5	1392 (10.8)	719 (9.1)	673 (13.5)	
	6+	4053 (31.5)	1385 (17.6)	2668 (53.5)	
Oxygen		6076 (47.2)	2745 (34.8)	3331 (66.8)	<.001
Suction		3594 (27.9)	1454 (18.5)	2140 (42.9)	<.001
CPAP/BiPAP		2820 (21.9)	1363 (17.3)	1457 (29.2)	<.001
Cough Assist		621 (4.8)	159 (2)	462 (9.3)	<.001
Tracheostomy		2125 (16.5)	521 (6.6)	1604 (32.2)	<.001

Vest	527 (4.1)	157 (2)	370 (7.4)	<.001
Ventilator	1007 (7.8)	127 (1.6)	880 (17.7)	<.001
Apnea Monitor	2876 (22.4)	2518 (32)	358 (7.2)	<.001

Children who use RMES at home may need both inpatient and outpatient healthcare services. Outpatient services include the following: emergency room, dental care, primary care, specialty care, laboratory testing, mental health services and substance abuse (MH/SA) care, obtaining medication, therapist care, durable medical equipment (DME) support, and home healthcare (HH) services.

The most common healthcare services utilized by children who use RMES at home were the following outpatient services: medications (95.6%), primary care (92.5%), specialty care (87.9%), and laboratory testing (88%). Inpatient services were utilized by 39.2% of children who use RMES at home. Notably, 57.2% of these children utilize other outpatient services, not included in the classifications used in this study.

Table 4: Number and Percentage of Children Utilizing Each Healthcare Service

Health Service	Overall	Cohort Type		
		Incident	Prevalent	p
Inpatient	5042 (39.2)	3453 (43.8)	1589 (31.9)	<.001
Outpatient				
ED	7151 (55.6)	4695 (59.6)	2456 (49.3)	<.001
Dental	4699 (36.5)	2674 (33.9)	2025 (40.6)	<.001
PCP	11893 (92.5)	7396 (93.9)	4497 (90.2)	<.001
Spec/ Non-PCP Prof	11306 (87.9)	6714 (85.2)	4592 (92.1)	<.001

Testing	11314 (88)	6981 (88.6)	4333 (86.9)	0.004
Other	7358 (57.2)	4250 (54)	3108 (62.4)	<.001
MH/SA	5268 (41)	2726 (34.6)	2542 (51)	<.001
Medication	12292 (95.6)	7504 (95.3)	4788 (96.1)	0.031
Therapy/Treatment	7637 (59.4)	4513 (57.3)	3124 (62.7)	<.001
DME	10326 (80.3)	5861 (74.4)	4465 (89.6)	<.001
HH	2621 (20.4)	1570 (19.9)	1051 (21.1)	0.113

Total spending on healthcare services for children who used RMES at home in 2013 was $737,198,077 USD. Of this amount, 57% ($421,855,396 USD) was spent on inpatient care. Outpatient services with the largest total expenditures by service were specialty care, medications, therapist care, MH/SA care, and HH services. Notably, the costs associated directly with DME were not one of the most expensive components of total healthcare spending for children who used RMES at home.

Table 5: Total Spending in USD For Children Who Utilized Each Healthcare Service

Health Service	Overall	Cohort Type	
		Incident	Prevalent
Inpatient	421,855,396	338,528,340	83,327,056
Outpatient			
ED	7,654,009	4,997,546	2,656,462
Dental	1,923,259	1,257,971	665,288
PCP	9,774,133	7,107,950	2,666,183
Spec/ Non-PCP Prof	150,782,980	39,995,821	110,787,159
Testing	9,326,776	5,576,239	3,750,537

Other	8,738,307	3,522,875	5,215,432
MH/SA	22,220,800	8,622,613	13,598,187
Drug/Inj	43,052,383	16,064,529	26,987,854
Therapy/Treatment	25,301,272	13,442,674	11,858,598
DME	16,041,801	6,533,517	9,508,284
HH	20,526,961	4,511,191	16,015,769
TOTAL	737,198,077	450,161,268	287,036,809

The number of healthcare encounters a child with RMES support at home has with professionals from a specific healthcare service are indicative of how often children require each service, and which are more frequently used than others. Within a year, the healthcare services that required the highest number (presented as median value of set) of unique day encounters were the following: medications (20 days), MH/SA care (10 days), specialty care (8 days), primary care (6 days), DME support (6 days), and HH services (6 days).

Table 6: Median (IQR) Number of Unique Day Encounters for Children Who Utilized Each Health Service

Health Service	Overall	Cohort Type		
		Incident	Prevalent	p
Inpatient	1 [1, 2]	1 [1, 2]	1 [1, 2]	<.001
Outpatient				
ED	2 [1, 3]	2 [1, 3]	2 [1, 3]	<.001
Dental	2 [1, 2]	2 [1, 3]	2 [1, 2]	<.001
PCP	6 [3, 11]	7 [4, 12]	5 [3, 9]	<.001
Spec/ Non-PCP Prof	8 [3, 30]	5 [2, 15]	19 [6, 79]	<.001

Testing	4 [2, 7]	4 [2, 7]	4 [2, 8]	0.219
Other	3 [1, 7]	3 [1, 6]	4 [2, 8]	<.001
MH/SA	10 [2, 33]	7 [2, 26]	13 [3, 40]	<.001
Drug/Inj	20 [8, 51]	14 [7, 32]	39 [14, 80]	<.001
Therapy/Treatment	3 [1, 15]	2 [1, 9]	6 [2, 25]	<.001
DME	6 [2, 12]	4 [2, 10]	11 [4, 15]	<.001
HH	6 [2, 51]	4 [2, 10]	46 [6, 194]	<.001

Per member per year payments refer to the dollar amount paid to a provider (hospital or healthcare profession) each year for each person for whom the provider is responsible for healthcare delivery. This is the system by which managed care organizations pay providers, and in this paper the payer in question in Medicaid. Of the payments made for children who use RMES at home, most PMPY payments were for hospitalizations/inpatient care (57%), specialty care (24%), and medications (6%). Less than 3% of payments were for RMES or home nursing (indicated by DME and HH).

Table 7: Total Annual PMPY Medicaid Payments For Children Who Utilized Each Healthcare Service

Health Service	Overall	Cohort Type	
		Incident	Prevalent
Inpatient	2733	3581	1393
Outpatient			
ED	50	53	44
Dental	12	13	11
PCP	63	75	45
Spec/ Non-PCP Prof	977	423	1852

Testing	60	59	63
Other	57	37	87
MH/SA	144	91	227
Drug/Inj	279	170	451
Therapy/Treatment	164	142	198
DME	104	69	159
HH	133	48	268
TOTAL	4777	4762	4799

PMPY payments in propensity-matched children using vs. not using RMES were $45,892 vs. $15,036 ($p < 0.001$). In adjusted analysis of PMPY payments, there were significant ($p < 0.001$) increases in payment by use of CPAP/BiPAP (+$1,117), oxygen (+$3,525), cough assist (+$6,342), suctioning (+$8,569), tracheostomy (+$11,977), vest (+$11,999), apnea monitor (+$13,747), and ventilator (+$32,323). In Table 8, the estimate values presented are increases in payment for use of the specific RMES, compared to no use.

Table 8: Regression Analysis of Exposure to RMES and Total Cost

RMES (used vs. not used)	Estimate	t Value	Pr > |t|	Alpha	Lower Limit	Upper Limit
Oxygen	3,525	19.38	<.0001	0.05	3168.56	3881.69
Suction	8,569	20.38	<.0001	0.05	7744.96	9393.66
CPAP BiPAP	1,117	5.42	<.0001	0.05	713.32	1521.29
Cough Assist	6,342	4.65	<.0001	0.05	3667.64	9015.63
Tracheostomy	11,977	7.96	<.0001	0.05	9028.74	14925
Vest	11,999	7.41	<.0001	0.05	8824.49	15174
Ventilator	32,323	8.68	<.0001	0.05	25026	39620
Apnea Monitor	13,747	25.9	<.0001	0.05	12707	14788

Table 9: Propensity Match of Children Who Use and Do Not Use RMES By Age and CCC. Cases include children who used RMES, and controls include children who did not use RMES. Variables used in the propensity score: BOE, CCC, CCI. Weights: Propensity Score (20%), Age (20%), Resp CCC (20%), Tech Dependency (20%). 11,306 cases matched to at least 1 control: 1,420 (12.6%) matched to 1 control, 9,886 (87.4%) matched to 2 controls.

Variable		Overall	Control	Case	p	Standardized Difference
Age group	0	8 (0)	4 (0)	4 (0.1)	0.052	0.04
	1-4	6693 (30.1)	4464 (30.8)	2229 (28.9)		-0.04
	5-12	8304 (37.4)	5373 (37.1)	2931 (38)		-0.85
	13-17	4575 (20.6)	2963 (20.4)	1612 (20.9)		0.01
	18+	2623 (11.8)	1689 (11.7)	934 (12.1)		0.01
BOE	Blind/Disabled Individual	8478 (38.2)	5463 (37.7)	3015 (39.1)	0.039	0.03
	Other	13725 (61.8)	9030 (62.3)	4695 (60.9)		-0.03
Neuromusc ccc		6539 (29.5)	4176 (28.8)	2363 (30.6)	0.004	0.04
CVD ccc		3814 (17.2)	2401 (16.6)	1413 (18.3)	0.001	0.04
Respiratory ccc		2198 (9.9)	1230 (8.5)	968 (12.6)	0.000	0.13
Renal ccc		1119 (5)	705 (4.9)	414 (5.4)	0.101	0.02
GI ccc		5398 (24.3)	3365 (23.2)	2033 (26.4)	0.000	0.07
hemato/ Immuno ccc		1241 (5.6)	805 (5.6)	436 (5.7)	0.756	0.00
Metabolic ccc		2432 (11)	1582 (10.9)	850 (11)	0.804	-0.46
Congenital/genetic ccc		4391 (19.8)	2730 (18.8)	1661 (21.5)	0.000	0.07
Malignancy ccc		2846 (12.8)	1758 (12.1)	1088 (14.1)	0.000	0.06
Neonatal ccc		1095 (4.9)	646 (4.5)	449 (5.8)	0.000	0.06
Tech dependent ccc		4564 (20.6)	2691 (18.6)	1873 (24.3)	0.000	0.14
Transplant ccc		178 (0.8)	109 (0.8)	69 (0.9)	0.256	0.01
Any ccc		13941 (62.8)	8976 (61.9)	4965 (64.4)	0.000	0.05
CCC Body Systems	0	1444 (6.5)	960 (6.6)	484 (6.3)	0.002	-0.01
	1	2773 (12.5)	1837 (12.7)	936 (12.1)		-0.02
	2	2790 (12.6)	1814 (12.5)	976 (12.7)		0.01
	3	3038 (13.7)	1983 (13.7)	1055 (13.7)		0.00
	4	3120 (14.1)	2060 (14.2)	1060 (13.7)		-0.01

	5	3030 (13.6)	2045 (14.1)	985 (12.8)	-0.04
	6+	6008 (27.1)	3794 (26.2)	2214 (28.7)	0.06

DISCUSSION

This study shows that utilization of RMES by children can identify additional projected healthcare costs, beyond consideration of chronic diagnoses. Understanding how RMES use impacts spending on services such as inpatient and outpatient care initiates a broader conversation about which aspects of service delivery for these patients – equipment and supplies, medications, hospitalizations, etc. – have higher associated costs and the development of guidelines to reduce costs and optimize health.

The attributes of children who use RMES at home show the increased complexity of care required for these patients prior to initial discharge from the hospital and as part of routine post-discharge care. Patients with multiple CCCs and MTA may need communication, proactive care planning, follow-up appointments with multiple outpatient specialty providers, equipment specialists, and home nursing at and after discharge.[17,26] The success of these strategies to reduce hospitalizations in children who use RMES at home is at risk if outpatient providers and the health system are ill-equipped or unprepared to meet the health care needs of this highly vulnerable population.[26]

Neuromuscular CCCs were the most prevalent disease group among children who use RMES at home. Children with neuromuscular conditions are at high risk for uncoordinated care, unmet healthcare needs, and overuse of outpatient services. These individuals are especially vulnerable to healthcare service issues when attempting to

transfer from pediatric to adult care.[27] Efforts to streamline and improve care coordination, follow-up of healthcare needs may improve health outcomes in children with neuromuscular conditions and decrease resource utilization and spending. Further investigation is needed to determine how to truly decrease spending and improve the health of this patient population.

Because most of the cost of using RMES is due to inpatient and specialty care rather than the equipment itself, RMES may indicate – broadly - medical fragility and increased healthcare needs. Results from this study show that the highest costs associated with RMES use are due to hospitalizations, specialty care, and medications. Efforts to reduce healthcare spending and resource utilization may be most effective if they address these aspects of care. For example, decreasing hospital readmissions among children with RMES may be an actionable, cost-saving step. Studies show that many readmissions among pediatric patients with complex conditions may be avoidable. Some patients are rehospitalized for a problem in the same organ system as their recent readmissions.[26] Prospectively identifying these patients and delivering effective readmission prevention service could potentially lead to a substantial reduction in expenditures on hospitalization.

Results from this study also demonstrated that the type of MTA assistance required by children who use RMES impacts healthcare costs. PMPY payments were highest for apnea monitors, ventilators, and vests, compared to other types of RMES. Identifying which RMES are associated with higher costs is an initial step, and further investigation is needed to evaluate if and how to influence spending on these

technologies. One important area of research for future studies is assessing whether more spending on certain health care services (i.e. inpatient care, specialty care, or home nursing) for children with RMES leads to better quality of care and contains costs.

Population health initiatives of children with medical complexity may benefit from consideration of RMES use in risk assessment for healthcare cost. Currently, health care reform initiatives are taking place to analyze shared accountability for patient health outcomes and healthcare resource utilization amongst community and hospital based clinician teams.[28,29] Episode-of-care experiments with a bundled payment for inpatient surgical and outpatient post hospitalization care have been associated with improved patient outcomes and reduced costs.[30] As demonstrated in this study, children who use RMES and are enrolled in Medicaid experience a variety of complex, multi-system medical conditions, and often depend on multiple RMES to maintain vital bodily function. Consideration of how current and potential future RMES use impacts a child's well-being and healthcare costs is important for developing effective, sustainable health initiatives.

There are some limitations in this study. Because the Truven MarketScan Databases do not disclose states in their database and there is no nationally representative database of children with Medicaid, the generalizability of data from this source remains unknown. Despite these limitations, this study suggests that efforts to reduce spending and resource utilization should not be focused on the costs of RMES themselves, but on costs related to inpatient and outpatient healthcare services for the population of children who use RMES at home. Further investigation in this area is needed, and may result in

critical insight on how to improve the health of these children in the hospital, home, and in their communities.

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