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RESEARCH ARTICLE

Activities of suppliers and technicians during the provision of complex and standard wheeled mobility devices

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Purpose: **The objective of this time-motion study was to document the type and duration of activities performed by wheelchair suppliers during the provision of wheeled mobility and seating devices.** ***Method:*** **Researchers observed eight rehabilitation technology suppliers and four rehabilitation technicians over two weeks in two metropolitan areas.** ***Results:*** **Data were collected on 500 client interactions, resulting in 864 activities that were classified as complex rehabilitation technology (CRT) or standard wheeled mobility equipment (STD). Data indicate that the majority of the activities were relatively short (median = 0.25 hours) but the distribution of activity durations was highly skewed. A difference existed in activity time across device complexity ($p = 0.039$), with CRT-related activities averaging about 0.1 hours longer in duration than STD activities. When assessing mobility types independently, activity times across device complexity differed for manual and power wheelchair at $p = 0.0001$ and $p = 0.086$ levels, respectively. When activities were tabulated into daily episodes for each client, CRT manual wheelchair times were higher than STD ($p = 0.003$), whereas power wheelchair episode times showed no difference across device complexity ($p = 0.245$).** ***Conclusion:*** **The results illustrate that the activities undertaken by suppliers during wheelchair provision vary widely and device complexity and device type impacts the types and duration of these activities.**

Keywords: Wheelchair, durable medical equipment, service delivery, time and motion

Implications for Rehabilitation

- The provision of wheelchairs and seating systems include a range of activities that extend before delivery to well past delivery of the equipment.
- Providing complex wheeled mobility and seating equipment requires more time, on average, that providing standard wheeled mobility and seating equipment.
- Activities that precede the delivery of equipment- including evaluation and configuring the equipment- are the most prevalent and time-consuming activities

Introduction

In the United States, Durable Medical Equipment (DME) is defined by the Centers for Medicare and Medicaid Services (CMS) to encompass respirators, prosthetic devices, canes, walkers, wheelchairs, wheelchair cushions and postural support devices [1]. By definition, DME must meet four criteria: "can withstand repeated use, is primarily and customarily used to serve a medical purpose, generally not useful to a person in the absence of an illness or injury, and is appropriate for use in the home."

Seating and mobility devices exemplify the breadth of DME, ranging from relatively simple standard manual wheelchairs to highly complex powered wheelchairs. Acquiring a wheeled mobility and/or seating device can follow different service delivery models. One model involves a prescribing physician, a therapist who performs an evaluation, and a supplier that provides the equipment. Each party's role can involve multiple activities. Because activities can vary substantially across clients and equipment, an interest in better defining and understanding these roles has emerged.

In 2009, the National Coalition of Rehabilitation Technology Suppliers (NCART) published a White Paper

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advocating for a category of complex rehabilitation technology (CRT) that is separate from standard wheeled mobility equipment (STD [2]). NCART distinguished CRT based on disability population, equipment complexity and breadth of services and suggested that additional services and expertize was needed based upon these factors.

Formal information about the services of wheelchair suppliers during provision of wheelchairs is limited. A report from the Office of the Inspector General [3] used Medicare claims data and the documentation submitted by wheelchair suppliers subsequent to the provision of powered wheelchairs. The report identified four categories of services: pre-delivery, during delivery, follow-up and other. The data indicated that 'during delivery' services were most prevalence and suppliers of standard and complex rehabilitation power wheelchairs reported performing five and seven services, respectively. This report represents the most detailed account of reported supplier activities but the methodology did not allow for an assessment of the time involved in these service categories.

Time and motion studies are used to track worker time dedicated to different types of activities. The methodology consists of an observer following subjects continuously and recording activities. The use of an observer has been shown to be more accurate and reliable than using self-reported data [4–6]. Time–motion methodologies have been used to study many different types of workers including healthcare professionals [4,5,7,8].

Only one study was found to have monitored activities related to the provision of wheelchairs. This study evaluated costs associated with wheelchair interventions and tracked time of physical and occupational therapists but did not assess activities of wheelchair suppliers [9]. To date, the time and activities undertaken by suppliers of wheelchairs have not been reported.

This study was designed to collect time and activities associated with the provision of wheeled mobility and seating devices. The aims were to document the activities of suppliers and compare the time and activities associated with CRT with those associated with STD.

Methodology

Participants

A list of all companies who provided wheeled mobility devices in Atlanta and Western New York were identified. Contact was made or attempted with all companies to identify those that met the following inclusion criteria:

- Have a minimum of $1.5 million in annual complex rehab sales per company location
- Employ at least 1 rehabilitation technology supplier (RTS) with a minimum of 3 years of experience
- Employ at least 1 technician

Each company manager was contacted by phone to determine if they met the inclusion criteria and were willing to participate. Once contacted, companies were assigned into one of 4 groups:

- Met inclusion criteria and agreed to participate
- Met inclusion criteria but declined to participate
- Did not meet inclusion criteria
- Declined to participate

A list of all qualified RTS's and wheelchair technicians was created from the companies that met inclusion criteria and agreed to participate. In Atlanta, 65 companies were contacted, 7 met the inclusion criteria and 5 of those agreed to participate. In Buffalo, 4 companies were contacted, 3 met the inclusion criteria and 2 agreed to participate. To minimize selection bias, all employees from these companies were grouped and randomly selected before being asked to participate in the study. In Atlanta, 14 RTS and 11 technicians formed the pool from which 4 RTS's and 2 technicians were randomly selected. In Buffalo, the same numbers of participants were selected from a pool of 12 RTSs and 5 technicians. Therefore, 12 subjects consented to participate in the study consisting of 8 RTS's and 4 technicians. Name and contact information was collected from all participants. Each was assigned a study-specific identification number that was associated with the data that they provided. The protocol was reviewed and approved by the IRBs from both research institutions.

Data fields

Data was collected on all activities that were seating and/or mobility related throughout the observation period. Data fields included information about mobility and seating equipment and the type of activities performed by the RTS or technician. Activities were logged in 15-minute units. In addition, data were recorded regarding client's disability, location of activity and presence of client during the activity.

Activities were categorized into 4 primary activities reflecting the state of the equipment delivery process. In addition, each activity was assigned a secondary activity reflecting additional specificity (Table I).

Table I. Primary and secondary activities associated with the provision of mobility equipment.

Primary activity categories	Secondary activity categories
Visit preparation	Intake/coordinate evaluation
	Obtain/prepare trial equipment
Pre-delivery	Assessment/equipment trial
	Home assessment
	Quoting/order parts
	Assemble WC
	Travel time
	Waiting
Delivery	Load/unload equipment
	Configure/fit/test WC
	Patient education
	Travel time
	Waiting
Follow-up	Adjust/test WC
	Maintenance
	Repair
	Quoting/order parts
	Travel time
	Waiting
Miscellaneous	Batch phone calls

Data collection tool

Custom data collection software was developed using HanDbase 3.1.2 for the iPod Touch. The prototype software was critiqued by an experienced seating clinician in Atlanta and two senior RTS's in Buffalo. Subsequently, research assistants in both cities pilot tested the software while shadowing RTS employees over multiple days. Feedback was obtained on activity categorization, related definitions, and expected response frequencies, and the data collection software was revised based upon the feedback. Four iPod Touch handheld devices were configured with the final version of the data collection software and a brief user's guide was created.

Data collection

Prior to data collection, participants signed consent forms describing the methods and requirements for the study. The research assistant also provided a 15–30 minute training session on the data fields, activity definitions and use of the data collection instrument.

The research assistant in each study location accompanied participants over a two week period. Both the research assistant and participant used identical data collection instruments to log all service events associated with consumers receiving mobility and seating equipment. The research assistant and participant independently entered data about each service encounter and its duration. Duration of activities was recorded in 15 minute units which required rounding the estimated time into discrete integers. For example, activities longer than 7½ minutes but less than 22½ minutes were recorded as 1 unit of time.

The research assistants and participants interacted throughout the data collection period to clarify data classification when novel situations arose. Typically, the suppliers provided information about client disability and equipment classifications. The research assistant s did not otherwise compare their data to that of the participants during the process. Only research assistant – collected time and activity data were used for this paper's analysis.

Classifying CRT and STD interventions

Mobility equipment was categorized using Healthcare Common Procedure Coding System (HCPCS) codes as defined by the CMS. Over 30 seating-related HCPCS codes are used when ordering equipment so a decision was made to classify seating and positioning equipment using grouping that reflect complexity. These are described below.

To classify equipment complexity, wheelchair HCPCS codes and seating system codes were sent to a third party who was knowledgeable about equipment coding but blinded to all other information about the clients and service activities. If either the wheelchair or seating system was classified as CRT, then all activities related to that client were considered a CRT intervention.

The following rubric was used to classify equipment as CRT:

Power wheelchairs with the following HCPCS Codes:
- Group 3: K0848–K0864
- Group 4: K0868–K0886

Manual wheelchairs with the following HCPCS Codes:
- E1161 E1229 E1234 E1235 E1231
- E1236 E1237 E1238 K0005 K0009

All other mobility device HCPCS codes were classified as STD. Descriptions of the numeric coding are included in Table III.

Seating system classification reflected equipment complexity and whether devices were individualized to the client. Pre-fabricated cushions and backrests were defined as typical off-the-shelf products that are available from most manufacturers. These devices were classified as Standard Equipment unless the seating system included a postural support component, such as lateral supports, hips guides, headrests, etc. The presence of postural supports placed a pre-fabricated seating system into the CRT category. Seats and backrests that were either made to users' measurements or custom-molded were classified as CRT.

Analysis of CRT and STD interventions

Descriptive statistics were compiled across CRT and STD categories to document the diagnoses of clients, wheelchair codes, and seating system classification. A series of analyses were performed to describe Activity Time across Device Complexity (STD vs CRT), and Device Type (Manual WC, Power WC, Scooter).

As noted, durations of activity were recorded in 15 minute units. Activity Time was calculated by dividing time units by 4 to obtain values in hours. Simple descriptive statistics were calculated to describe the time incurred while performing the different activity types. These values are reported to the nearest 0.1 hours. Given the sample sizes of these calculations, we believe that the marginal means are an accurate measure of the actual time and that a 6-minute resolution is appropriate as a reporting mechanism. Parametric analysis that compared different time-based variables would not be affected by transforming the data from units to hours.

A χ^2 analysis was used to discern differences in how time was distributed over activity type for CRT and STD interventions. A two-way univariate ANOVA was processed using Device complexity (CRT/STD) and activity type (Visit prep/pre-delivery/delivery/follow-up) as the main factors. The activity data was then partitioned to include only Manual and Power wheelchair entries in order to analyze the influence of Mobility Device Type in the provision of CRT and STD interventions. Univariate ANOVA was used to determine differences in Activity Time across Device Complexity for manual and power wheelchairs. Scooter-related activities were excluded from the analysis because, by definition, they only fall into the STD classification.

Activity time was also aggregated into 'daily episodes' to reflect the total amount of time that employees focused on a particular client in a given day. These daily episodes could consist of a single activity or a combination of activities. Daily episode times were calculated with and without the inclusion of travel time and were aggregated by mobility device type (manual, power and scooter). A two-way ANOVA compared daily episode time across device complexity (CRT and STD) and mobility device (manual wheelchair and power wheelchair).

An *a priori* decision was made to examine and discuss the results of all statistical analysis resulting in $p \leq 0.1$ levels. Due to the investigative and descriptive nature of this data, a slightly greater risk of Type I error was considered acceptable to achieve better descriptive ability. Actual p-values are reported for all analyses to allow the reader to assess results individually.

Results

A total of 1015 activities were documented. Of these, 864 were designated as activities associated with either CRT or STD devices and were assigned to one of four categories: visit preparation, pre-delivery, delivery and follow-up. The remaining activities either involved multiple clients (i.e. travel to a clinical setting) or were activities for which the device was unknown. For all the CRT–STD activities, the mean time incurred was 0.5 hours with the median and mode being 0.25 hours. Skewness naturally resulted from the floor effect (0 time units) resulting in distributions with a positive tail. Analysis of time utilized parametric approaches due to a sample size deemed adequate for such analysis [10].

A total of 500 clients were engaged during the study. Table II summarizes the distribution of client diagnoses across device complexity. Due to the number of cells with an expected cell count <5, a valid χ^2 analysis was not possible. However, calculation of odds ratios indicate that persons with cerebral palsy and spinal cord injury are more likely to receive CRT (OR = 4.6 and 41.1, respectively) whereas clients with arthritis and orthopedic impairment were more likely to receive STD (OR = 31.5 and 5.1, respectively).

Sixteen different categories of wheelchairs were provided to the clients (Table III). Ultralight manual wheelchairs, manual tilt-in-space wheelchairs and Group 3 power wheelchairs accounted for 86% of all CRT wheelchairs. K0004, Group 2 power wheelchairs and scooters accounted for 81% of all STD wheelchairs.

The distribution of the seating system categories is shown in Table IV. Based upon the classification system, only the Pre-fabricated cushions and backrests can be included in both the CRT and STD categories with the designations based upon the associated mobility device. About 40% of the seating systems fell into this pre-fabricated category.

Table II. Distribution of client diagnoses across device complexity.

Diagnosis	CRT	STD	Unknown	All
Absence lower extremity	4	3	0	7
Arthritis	2	21	0	23
Cardiovascular	1	8	1	10
Cerebral palsy	106	12	9	127
Cerebrovascular	25	16	5	46
Developmental disability	23	9	1	33
Diabetes	0	4	0	4
Neuromuscular	78	20	7	105
Obesity	2	7	2	11
Orthopedic impairment	14	24	0	38
Pulmonary	0	7	0	7
Spinal cord injury	80	1	8	89
All	335	132	33	500

Activity distribution and the time incurred during each activity are tabulated in Tables V and VI. The distribution of activity types differed across Device Complexity ($\chi^2 = 33.4$, $p < 0.001$) with CRT devices having a greater percentage and STD having a lesser percentage of follow-up activities than expected. Alternatively, CRT had less pre-delivery activities than expected with a greater number of pre-delivery activities associated with STD.

Results of the two-way univariate ANOVA indicate that activity time differed across device complexity (CRT vs STD)

Table III. Mobility device classifications across device complexity.

	CRT	STD	All
Standard wheelchair (K0001)	2	13	15
Lightweight wheelchair (K0003)	7	18	25
High strength, lightweight wheelchair (K0004)	6	30	36
Ultralightweight wheelchair (K0005)	168	0	168
Heavy duty wheelchair (K0006)	0	2	2
Extra heavy duty wheelchair (K0007)	0	5	5
Other manual wheelchair-base (K0009)	32	0	32
Manual adult-includes tilt-in-space (E1161)	158	0	158
Pediatric manual tilt-in-space (E1232)	8	0	8
Pediatric, manual folding w seating system (E1236)	4	0	4
Group 1 power wheelchair (K0813–K0816)	0	8	8
Group 2 power wheelchair (K0820–K0843)	16	128	144
Group 3 power wheelchair (K0848–K0864)	194	0	194
Group 4 power wheelchair (K0868–K0886)	10	0	10
Power wheelchair, group 5 pediatric (K0891)	2	0	2
Scooter	0	50	50
No value	1	2	3
All	608	256	864

(HCPCS codes are included parenthetically).

Table IV. Seating system classification across device complexity.

	CRT	DME	TOTAL
Pre-fabricated seat/back	143	187	330
Pre-fabricated with supports	111	0	111
Made to measure seat/back	224	0	224
Custom-molded seat/back	24	0	24
Combination of above	52	0	52
No value	58	73	131
Total	612	260	872

Table V. CRT activity.

Activity (hrs)	N	Mean	SD	Minimum	Median	Maximum
Visit preparation	16	0.3	0.14	0.25	0.25	0.75
Pre-delivery	303	0.6	0.45	0	0.5	2.5
Delivery	105	0.5	0.38	0	0.25	1.75
Follow-up	184	0.5	0.45	0	0.25	2.25

Table VI. STD Activity time (min).

	N	Mean	SD	Minimum	Median	Maximum
Visit preparation	10	0.2	0.12	0	0.25	0.5
Pre-delivery	161	0.4	0.28	0	0.25	2.25
Delivery	55	0.4	0.44	0	0.25	2
Follow-up	30	0.4	0.24	0	0.25	1

at p = 0.037 and Activity type at a p = 0.098 level. The overall activity time mean for CRT interventions was 0.5 hours and the STD average was 0.4 hours. The interaction between the main effects was not significant (p = 0.270).

Using univariate ANOVA, comparisons of each individual activity across device complexity found that pre-delivery activities were longer for CRT interventions than in STD interventions (p < 0.0001). No other individual differences in activity time reached significance across device complexity.

For manual wheelchairs, ANOVA analysis indicated that CRT activity time was greater than STD activity time (p = 0.001) with means of 0.5 and 0.4 hours, respectively. For power wheelchairs, the analysis indicated that CRT Activity Time was greater than STD activity time at a p = 0.086 level with means of 0.5 and 0.4 hours, respectively. Standard deviations of the activity times were high with the coefficients of variation exceeding 0.75 (Table VII).

Activity time was aggregated into daily episode times and compiled according to device complexity (CRT vs STD) across the different types of mobility devices (manual wheelchair, power wheelchair and scooter). The results are included in Tables VIII and IX.

The General Linear Model, used to compare daily episode time across device complexity and mobility device type, found interactions between Equipment complexity and mobility device type for daily episode variables with travel (p = 0.049) and without travel (p = 0.067) times included. This indicates that the two main effects are not independent of each other and the differences in daily episode time used to provide CRT and STD depends on whether a power or manual wheelchair is being provided.

Table VII. Activity time (hrs) across device complexity and wheelchair type.

	N	Mean	SD
CRT manual WC	384	0.5	0.45
STD manual WC	69	0.4	0.3
CRT power WC	227	0.5	0.41
STD power WC	140	0.4	0.34

CRT, complex rehabilitation technology; STD, standard wheeled mobility equipment; SD, standard deviation.

When considering daily episode times of each device type separately, manual and power wheelchair results differed. Daily episode times when providing CRT manual wheelchairs were longer than when providing STD manual wheelchairs whether including travel (p = 0.052) or not including travel (p = 0.003). Conversely, for power wheelchairs, the daily episode time per client did not differ for CRT devices versus STD devices either when including (p = 0.53) or excluding (p = 0.14) travel time. Overall, travel increased the average daily episode times by about 35%.

Discussion

This cross-sectional study offers insight into the daily activities of RTSs and Technicians as they provided wheeled mobility and seating interventions. Regardless of equipment complexity, the majority of activities were relatively short with the median and mode being 0.25 hours, except for pre-delivery activities for CRT which had a median duration of 0.5 hours. However, maximum durations for pre-delivery, delivery and follow-up activities were greater than or equal to an hour for both CRT and STD equipment.

The distribution of activities across device complexity varied. The finding that clients with CRT devices required a disproportionately high number of follow-up activities is not surprising. By definition, these clients tend to have greater functional and/or postural needs and, therefore, require more attention after delivery. The finding that STD equipment was associated with more pre-delivery activities was somewhat unexpected. To better understand this result, a χ^2 analysis was run on pre-delivery activities. The result (p < 0.001) indicated that home assessments and travel, were disproportionately more frequent for STD compared to CRT interventions.

A significant difference existed in activity time across device complexity with CRT activities averaging about 0.1 hours longer in duration than the average STD activity time. With respect to individual activity types, only pre-delivery activities were significantly greater in CRT interventions, requiring, on average 0.2 hours more time. In combination with the finding described above, this can be considered an important finding about the frequency of pre-delivery activities. While the

Table VIII. Daily episode times without travel device complexity and mobility device type.

		N	Mean	SD	Minimum	Median	Maximum
Manual WC	CRT	256	0.6	0.57	0	0.5	4.5
	STD	41	0.4	0.18	0	0.25	0.75
Power WC	CRT	161	0.6	0.45	0	0.5	2.25
	STD	80	0.5	0.27	0	0.5	1.25
Scooter	STD	26	0.4	0.3	0	0.25	1.5

Table IX. Daily episode times including travel across device complexity and mobility device type.

		N	Mean	Std.Dev	Minimum	Median	Maximum
Manual WC	CRT	256	0.8	0.7	0	0.5	4.5
	STD	41	0.6	0.49	0.25	0.5	2.75
Power WC	CRT	161	0.7	0.58	0	0.5	3.25
	STD	80	0.8	0.58	0	0.5	2.5
Scooter	STD	26	0.7	0.43	0.25	0.5	2

Abbreviations: CRT, complex rehabilitation technology; STD, standard wheeled mobility equipment; SD, standard deviation.

dataset of CRT activities involved disproportionately fewer pre-delivery activities, the added complexity of assessment, ordering and configuring CRT wheelchairs required more time, whereas the actual delivery and follow-up did not require additional time, on average.

Travel was found to be a significant factor in the delivery of wheeled mobility and seating devices. Adding travel to daily episodes of activity increased duration by 35%. Managing and optimizing travel, therefore, should be a paramount consideration of companies that provide mobility equipment. While this result might have been biased by the two study locations, one cannot presuppose that smaller or less urban settings would necessarily result in less travel times. The study of different types of municipalities should be performed to better understand travel's influence on employee time.

When considering only manual and power wheelchairs, activities required more time for clients receiving CRT compared to STD, on average. This result is not particularly surprising to those hypothesizing that clients with greater functional limitations and greater device complexity would require more time in providing mobility equipment. A review of the full data distribution indicates that CRT interventions had a greater number of long activity times. The 75th percentile for CRT and STD activities was 0.75 and 0.5 hours, respectively. More advanced analysis may be able to identify the combination of factors that require disproportionately greater time to better predict longer activity durations.

In analyzing daily episode times, the influences of device complexity and mobility device were not independent of each other. Therefore, the differences in daily episode time used to provide CRT and STD depends on whether a power or manual wheelchair is being provided. Subsequent analysis indicated that the daily episode times for the delivery of complex manual wheelchairs required more time than standard manual wheelchairs whereas the daily episode time spent in the delivery of power wheelchairs did not differ across device complexity. This finding makes clinical sense considering the number of options and adjustments available on complex manual wheelchairs, whereas the field adjustability of power wheelchairs is not as great.

Several limitations should be considered when assessing the results. Studies that involve continuous observations typically collect data on a small number of people but collect more accurate data at great depth [5]. Nonetheless, external validity needs to be judged by the fact that data was collected in only two cities and by following 12 people. Sampling bias within those locations is not expected since the subjects were randomly selected from all qualifying persons in each city. Selection bias was potentially introduced by recruiting only companies meeting a defined threshold of employees and at least $1.5 million in CRT sales. This sales threshold was established to ensure inclusion of companies that performed substantial CRT interventions. However, this excluded smaller companies so the results may not reflect all companies that provide wheeled mobility devices.

The cross-sectional research design does not collect the time involved during a complete wheeled mobility and seating intervention. Rather, the data is a compilation of 'snap shots' at various times in the process across many people. In the future, a longitudinal study including outcomes measurements should be attempted. This will require a different methodology since a research relationship with wheelchair users will be required.

Finally, all comparisons between CRT and STD reflect the CRT definition used in this study. Assigning specific wheelchair HCPCS codes and seating classifications in a different manner might alter the results. For example, a more conservative definition of CRT might result in a greater separation from STD. This data set could be used to assess other categorization schemes to evaluate how time and activity might change. We will be offering this data set for such a secondary analysis to interested researchers.

Conclusion

This time-activity study of the provision of wheeled mobility and related equipment represents the initial attempt to characterize the activities performed when providing wheelchairs and seating systems. The data shows that activity times vary widely but the majority of activities are relatively short. Certain interventions clearly require significant time, but these cannot be predicted by the definition of CRT used in this paper. Effort should be made to identify the combination of factors associated with long client interactions as a means to improve planning and service to these clients.

The finding that complex manual wheelchairs required more time in a given day than STD manual wheelchairs was not surprising based upon the definition of CRT. However, the results also found that complex power wheelchairs did not require a longer daily episode time compared to STD power chairs. This finding should be examined more closely.

While this study was limited to documenting the type and duration of activities, it also has value in working toward enhanced knowledge of assistive technology services and outcomes. The effectiveness of services associated with assistive technology device provision (e.g. assessment, fitting and training) is not well-supported by rigorous research evidence [11]. With few exceptions [9], clinicians and suppliers have not been furnished with research that substantiates the contribution of their services to appropriate device recommendations [12] and positive consumer outcomes [11]. The absence of data regarding practitioner time and activity appearing in AT outcomes research obviates the association of outcomes data with particular practitioner actions. This hinders the interpretation of individual study findings and impedes synthesis of results across studies [13]. A longitudinal study that tracks activity type and duration as well as outcomes would afford important information about the provision of assistive technology.

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