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A Comparative Expected Value Analysis Study to Determine the Cost Benefit or Cost Effectiveness of Early Discharge, Medical Transport, Home Health as Well as Home Care Devices, Services and Technologies in The United States

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ABSTRACT: It was found that Amazon products (Alexa™, Echo™, Halo™), EMRs, fire extinguishers, genome sequencing test, on-line pharmacies, remote patient monitoring, provided economic value, while emergency medical service membership programs**,** fire alarm subscription services, helicopter emergency medical services, home fire insurance policies, home fire sprinklers, and home security systems were not found to have provided economic value. Tele-health (virtual office visits) would provide economic value if most tele-health visits replaced existing in-person visits and the low cost virtual didn't drive demand for unnecessary visits. Robotic surgery technologies provide economic value if fully utilized (high patient demand to reduce overhead costs per procedure) in a facility with little excess capacity as long as it did not compete with non-robotic surgical offerings at the present facility. AEDs provide economic value if appropriately placed in high demand locales based on future probability of use.

KEYWORDS: Amazon Products, EMRs, fire alarm subscription services, genome sequencing test, home fire insurance policies, home fire sprinklers, home security systems, on-line pharmacies, remote patient monitoring, economic value, helicopter emergency medical service, tele-health (virtual office visits), robotic surgery technologies AEDs.

I. INTRODUCTION

The present study conducted cost benefit and effective analysis of 14 home healthcare devices, services and technologies used by patients and healthcare providers in the United States. Home physiological monitoring devices can record and report vitals to a home health agency or remote provider. Their active technologies that can detect falls and alert personal emergency response and passive systems can be embedded in the carpet that can detect falls. Fire sprinkler and alarm systems can alert home care patients of a fire. Security camera system can remotely monitor home care patient residences. Alexa (an Amazon product and service) can provide reminders on when to take medications or when it is time to exercise. There are also devices that help with the location of lost objects and assist with the dispensing of medications. There are numerous social networks available at no cost as long as you can endure pop up ads that can improve social connectedness for those who are homebound.

The annual cost of the technology, device or service was divided by the number of lives saved to determine the cost per life saved. Merrill (2017) reported that federal agencies value one's life as much as $10 million. Merrill (2017) referenced Richard Thaler, winner of the 2017 Nobel Prize in Economics, who calculated the value of one's life to be $1.5 million in today's dollars, and cited W. Kip Viscusi, professor of law and economics at Vanderbilt University, who applied a 37 percent lower life value for people 65 and older, which comes to around $945,000 ($1,500,000 * 0.63). However, the average amount state and local governments are able to collect from a single tax-payer is significantly less than these benchmark amounts. On average, state and local governments collected $1,144 per person, but collections vary widely from state to state (Loughead, 2018). Governments would quickly go bankrupt by spending significantly more than the amount of taxes collected per taxpayer on technologies to save lives.

Not all individuals are able to manage the technological acumen required to operate some of these devices and services. But in combination with caregivers, healthcare professionals, and friends/family, all these devices and services are viable options to assist in caring for an individual.

II. RESULTS

Automated External Defibrillator (AED) - NIH (2018) estimated that each year more than 18,000 Americans have a shockable cardiac arrest outside of a hospital that occurs in public with witnesses. They further estimated that 1,700 lives

are saved annually in the United States from bystander use of automated external defibrillators (AEDs). Features and costs vary from device to device, but a new AED can cost as little as $1,275 for a professional-rated device with a shelf life of two to four year (AED.com). According to Zarilli (2015), nearly 100,000 automated external defibrillators are sold each year so the total amount spent was roughly $127,500,000 ($1,275 * 100,000). Spending $127.5 million annually to save 1,700 lives would come in at $75,000 cost per life saved, which seems to suggest that AEDs would provide economic value if appropriately placed in high demand locales.

Amazon products – Echo and Alexa provide patient reminders, information and quick tips on personal care provide economic value due to the minimal effort and no monthly subscription fees. Amazon's Halo Health™ remote patient-monitoring device tracks sleep, movement, and heart rate location in the event of a fall. The device also provides smart recommendations on how to improve your health. The subscription cost for both Halo Fitness™ and Halo Nutrition™ is around $50 per year. Amazon also offers a full year of the service for free with the purchase of a new Halo View™ fitness tracker, which retails for around $80. Alexa Care Hub™ is free and provides family members notifications through the Alexa app when the user calls for help to a first responder. Amazon's Alexa Together™, a subscription-based service helping caregivers provide remote support to elderly loved ones, costs $199 per year. The service provides fall detection and 24/7 emergency assistance supporting the health and wellbeing of older users. The combined cost of all these technologies is about the same cost as a single primary care office visit and can save seniors thousands of dollars per month compared to the cost of a retirement centre, thus extending the amount of time an individual can stay in their home.

Electronic Medical Record (EMR) - An EMR is cost-effective since the cumulative net present value (NPV) was positive. The positive NPV was attributed to both cost reductions and additional revenues. EMR had a 6.18-year payback period that did not include any qualitative benefits that the paper-chart system would provide (Choi et al, 2013). Most of the savings are from minimizing drug expenditures, better capture of charges, decreased billing errors, and much more. Implementation of EMRs has been a battle for some organizations struggling to make the transition (Banner Health) while others have benefitted ten-fold from implementing the system. Initially implementing EMRs can become costly, however, the estimated DDP (delivery duty paid) is an impressive 6.18 years although management may not be fond of waiting that length of time (Choi, Lee, Rhee, 2013). The estimated benefit from using EMRs over a 5-year period is about $86,400 per provider (The American Journal of Medicine, 2003). Most of the savings are from minimizing drug expenditures, better capture of charges, decreased billing errors, and much more. There are other indirect economic benefits from implementing EMR systems such as saving time in transferring patient data and providing smarter public health measures saving healthcare providers time to allocate to their practice, and potentially saving the patients money from misdiagnosis and drug expenses. In conclusion, using the EMR system is an investment that provides economic value however the amount of value is dependent on several key factors.

Genome Sequencing Test – The genome sequencing test helps determine the future risk of developing certain diseases (Mayo Clinic, 2020). The at-home administered test costs around $100. Genome sequencing testing provides disease risk and health condition information, such as carrier status for genetic diseases, genetic risk of cancer, type-2 diabetes, Alzheimer's disease, and many other conditions. Most of the included studies had favourable economic evaluation results, as well as concrete evidence demonstrating the clinical utility of pre-emptive genotyping (Simeonidis et al, 2019). A decision analytical model study found that genomic screening for HBOC among unselected women may be cost-effective depending on the age distribution of the women screened (Guzaukas et al, 2020). A team of researchers used an 'input–output' economic model to calculate a 141-fold return on each dollar invested in the Human Genome Project (Drake, 2011). As a result, genomic sequencing has been growing exponentially as technology is rapidly advancing. From 1998 to 2010 human genomic sequencing projects, research and other industry activities have generated an output of $796 billion having provided 3.8 million job-years of employment (Battelle Technology Partnership Practice, 2011). Hence, value per life saved ($1.5 mil) is much more than the cost per life saved ($694,444).

Helicopter Emergency Medical Service - Four reliable studies showed an overall reduction in mortality of 2.7 lives saved per 100 helicopter emergency medical service deployments (Ringburg, et al., 2018). The National Association of Insurance Commissioners (NAIC) reported that the average cost to transport a patient on an air ambulance is around $18,750 (Araujo, 2019). The cost to transport 100 patients would total $1,875,000, which would result in an overall reduction in mortality of 2.7 lives resulting in the cost per life saved to be $694,444 ($1,875,000/2.7).

Home Fire Insurance Policy - Fire insurance does not provide economic value once the cost of the policy and the net savings from fire damage as well as the probability of a fire are taken into consideration. The National Fire Protection Agency (2017) reported that United States fire departments

responded to 358,500 home structure fires that caused $6.7 billion in fire damage. According to Statista (2018), there were 127.59 million households in the United States making the probability that one's home will catch on fire during any given year 1 in 356.39 (358,000 home fires/127,590,000 households = 0.0028). The average annual cost per household for fire damage is $52.51 ($6.7 billion in fire damage / 127.59 million households). According to Value Penguin (2019), the average annual cost of a homeowner's fire insurance policy was $1,083 nationwide. Therefore, the average expected value of fire insurance policy would be 0.0484 ($52.51/ $1,083) so those who purchased a fire insurance policy receive on average a return of less than five cents (0.0484) for every dollar invested.

Home Fire Sprinklers - Home fire sprinkler systems do not provide economic value once the cost of a fire sprinkler system and the net savings from fire damage as well as the probability of a fire are taken into consideration. The United States Fire Administration (2019) found that the average cost of fire damage in a house with and without fire sprinklers was $2,170 and $45,110, respectively. The average cost of installing home fire sprinkler systems was $1.61 per square foot of space under sprinkler or around $3,000 per house. Therefore, the expected annual cost of a $3,000 fire sprinkler system that lasts 20 years before replacement would be $150 ($3,000/20 years). The expected value of a fire sprinkler system saving $42,940 ($45,110 - $2,170) per fire would be $120.61 ($42,940*0.0028) per year. The expected value of a $3,000 fire sprinkler system would be $2,412.20 ($120.61 * 20 years). Those who purchase a fire sprinkler system receive an average return of 80.40 cents ($120.61/ $150 = 0.1022) for every dollar invested.

Emergency Medical Service Membership Program - Emergency medical service membership programs do not provide economic value once the cost of the membership program and the net savings from avoiding out-of-pocket expenses for hospital transport and paramedic response are taken into consideration**.** Some fire departments are charging fees for responding to emergency medical calls even when they do not transport someone to the hospital in order to recover response costs. Residents can avoid the per-response fees by enrolling in the emergency medical service membership programs for $48 a year. Under the program, all permanent residents in the subscribing household can avoid out-of-pocket expenses for hospital transport and paramedic response.

According to the National Fire Protection Agency (2018), 22,750,500 fire department medical aid calls were made in 2016. Roughly 60 percent of the calls included transporting someone to the hospital. The ride can cost as much as the emergency room visit, ranging between $300 and $1200 (approximately a $750 average), tacking on fees for mileage and oxygen. This suggests that a 6.96 percent chance (based on a 327 million population) exists that someone living in a United States household will be assisted by an emergency medical service call in any given year (22,750,500 medical calls/327,000,000 households). The $48 membership would have an expected benefit of $31.32 [($750 * 60 percent) * 0.0696)] and a return of 65.25 cents ($31.32/$48) for every dollar invested into the medical service membership program. However, if the patient is a higher risk patient then this membership program may provide economic value.

Fire Extinguishers - Fire extinguishers do provide economic value once the total amount spent on fire extinguishers and the net savings from fire damage are taken into consideration. McSheffrey (2011) estimated that the 147,000 fires extinguished entirely by fire extinguishers reduced fire damage by $5 billion in 2010. According to an IBIS World Report (2019) the United States fire extinguisher manufacturing industry reached revenues of $1 billion in 2018. The $5 billion annual benefit realized from fire extinguishers is $4 billion more than the $1 billion cost spent on fire extinguishers. The expected benefit of $39.19 ($5 billion/127,590,000 households) exceeds the expected cost of $7.83 ($1 billion/127,590,000). Those who purchase a fire extinguisher receive an average return of $4.62 ($39.19 /$7.83 = 4.62) for every dollar invested.

Fire Alarm Subscription Services - According to the National Fire Protection Agency only 3.7 percent (1,342,000 out of 35,320,000) fire department calls are fire related. United States fire departments responded to a total of 2,622,000 false alarms in 2016 (Statista, 2018). Thus, fire departments responded to twice as many false alarms as they did to actual fire-related calls. The cost per response to a false alarm has been estimated to be around $1,000 per event, resulting in the estimated total cost of responding to false alarms to be around $2.6 billion dollars. The $2.6 billion cost of responding to false alarm amounts to about 40 percent ($2.6 billion/$6.7 billion in fire damage) of the total cost of fire damage. The economic benefit of a fire alarm and subscription service is essentially zero due to the almost universal availability of cell phones combined with 911 call centers. The annual false alarm economic cost per household is roughly $20.55 ($2,600,000,000/127,590,000 households), and the annual cost of the alarm and subscription service is around $250 per year. Those who purchase a fire alarm service receive an average return of about eight cents ($20.55/$250.00 = 0.0822) for every dollar invested.

On-line pharmacies - Express Scripts and Amazon pharmacy are accepted by most major insurance plans and provide economic value since they provide timely, more

convenient home delivery at no additional cost for the patient and often at lower co-pay cost than retail pharmacies.

Remote Patient Monitoring - Remote patient monitoring devices such as spirometers, thermometers, blood pressure cuffs, glucometers, pulse oximetry and heart rate monitors can passively collect data at home for off-site healthcare practitioners that monitor post-discharge patients and long-term home healthcare patients. Remote patient monitoring cost-effectively screen patients, diagnose conditions and track treatment administration and results efficiently by helping healthcare practitioners monitor, screen and diagnose medical conditions for their at-home patients. Remote patient monitoring technologies also empower patients to take ownership of their healthcare often minimizing hospitalizations and reducing readmissions (Kim, Campbell, de Ávila, Wang, 2019).

Therapeutic drug monitoring tracks patients' response to medication and alerts patients and healthcare practitioners of any adverse events (Garzón, Pinacho, Bustos, Garzón, Bustamante, 2019). Almost half of the U.S. population suffers from a chronic illness (Wu, Green, 2000). As a result, the global remote patient monitoring market is forecasted to reach $33.85 Billion by 2027 (Emergen Research, 2020). According to the 2021 AHA Annual Survey study (2021) the average per-day hospital cost in the U.S. was $2,883 and the average hospital stay was 4.6 days for a total average cost of $13,262, which is far more than the cost of equipment purchasing, servicing and cost of remote patient monitoring programs ranged from $275 to $7,963 annually per patient (Paretz, Arnaert & Ponzoni). Realizing the cost benefits, the CPT codes were revised in 2020 and remote patient monitoring is now covered by Medicare, Medicaid programs across 34 states along with multiple private payers. The total cost savings for remote monitoring technology were projected to be $425 per-person- per month, with an annual savings of $5,069. (Schneider, Cooper, Scheibling, Parikh, 2020).

Robotic surgery – A systematic review of robotic surgery in gynecology, one study found that robotic surgery conferred shorter hospital stay in comparison to open surgery due to a lower proficiency plateau. Thus, the evidence indicates that robotic techniques do present significant advantages over other gynecologic procedures (Gala et al, 2014). In a comparison of pediatric urologic robotic-assisted laparoscopic surgery versus open surgery one study found that the direct costs of robotic-assisted surgery were 11.9% lower. The main cause of this cost difference was the reduced hospital length of stay (Rowe et al, 2012). Robotic surgery fixed capital costs, robot maintenance contracts, and disposables increase the cost of robotic by $2,264.35 per patient over open surgery (Ho et al, 2011). However, hospitals after spending the additional $2,264.35 per-procedure end up with $1,200 net cost savings per surgery due to the benefit from the reduced length of hospital stay, which explains the increased adoption of robotic surgery technologies (Advisory Board, 2010). However, the $1,200 net savings is only possible if the robotic technology is fully utilized (high patient demand) in a facility with little excess capacity and not cannibalizing other surgical offerings at the acquiring facility.

Security - Money is the most common stolen item (19%), then jewelry (18%), followed by firearms. Electronics such as laptops, cameras, phones and televisions are also high on a burglar's list of desirable items (Parish, 2017). If a homeowner has no cash, firearms, jewelry or expensive electronic items then their risk of loss if they are robbed would be insignificant.

Storing valuables in a $500 home safe that has a 25-year life span is a convenient and a relatively cost-effective way to minimize cost associated with a robbery. A safe would eliminate virtually all losses from burglaries committed by non-professionals, which according to Bera (2019) would be 85% of them. A small safe to store jewelry and cash is an easy way to prevent two of the most common theft items from being targeted.

According to a report published by the Australian Institute of Criminology, based on interviews with 65 West Australian-based burglars, a dog was an effective deterrent 61% of the time. It wasn't so much the fierceness of the dog that scared off burglars, but the dog barking and drawing attention to what's going on. The next most common deterrent was a working alarm system at 49%, followed by sensor lights ($35) at 23% (Davis, 2015). The combined cost of an alarm system, security screens and sensor lights is likely to be less over the long-term than the cost of owning a dog. However, dogs only provide value as a theft deterrent if the value of companionship exceeds the cost of pet ownership.

In 2016, 278,600 break-ins occurred at night, 486,006 happened during the day and on average $2,361 was stolen (McCarthy, 2018). According to the latest FBI Uniform Crime Reporting Statistics (FBI, 2019) the burglary rate in 2015 were 542 per 100,000 household (.00542). Therefore, the expected annual cost of break-in per household would be $12.79 ($2,361 * .00542). The annual cost of an ADT alarm system is $335.88 (12 * $27.99). Vivent has an annual cost of $479.88 (12 * $39.99) and the Brinks plan has a starting cost of $249 for the equipment and then an annual cost of $348 (12 * $29). All of which exceed the expected annual cost of break-in per household which is $12.79 ($2,361 * .00542).

Roughly 1.9% of the average payout amount for insurance is for theft and the average cost of homeowner's insurance in the U.S is $1,083 per year (Penguin, 2019). Therefore, the expected value of the insurance policy would be $20.57 ($1,083 *.019), which is about $7.78 (20.57 - $12.79) more than the expected annual cost of a break-in per household would be $12.79 ($2,361 * .00542), not including the additional cost of a $500 average deductible (Penguin, 2019). Homes without a security system have a 300% more chance of getting broken into (Bera, 2019) so a home security system would reduce the probability of a break-in by .0018 (.00542 / 3) or 180 break-ins per 100,000 households.

	Cost	SR	Expected Cost	Expected Benefit	Net Benefit
No Valuables	-	100 %	-	$12.79	
Insurance	$20.57	-	-	$12.79	-$7.78
Safe	$20	85%	$23.52	$12.79	-$10.73
Sensor lights	$35	23%	$152.17	$12.79	-$139.38
Alarm system	$335.88	49%	$685.47	$12.79	-$672.68
Dog	$500	61%	$819.67	$12.79	-$806.88

In order to further understand home burglaries and their prevention, aside from precautions that may be taken, it is crucial to identify how these burglaries occur. When comparing burglaries occurring through windows vs. home doors, evidence suggests that doors are at higher risk. Roughly 34% of burglars use the front door, 22% use the back door and 23% use first-floor windows (Jones, 2019).

Therefore, investments in both door and window protection can greatly lessen the probability of a home break in. Various safety precautions such as shatter-proof windows, or window bars are few examples one may take to halt a home burglar. An average home in the United States has about 8 windows. Comparing the table data, shatter proof windows have a significantly higher cost at $2,400 versus $800 for window bars perhaps for aesthetic purposes. Additionally, locks are a crucial aspect of home burglaries. Whether they occur through unlocked doors or forced entry these break-ins account for 34% of burglary methods. It is suggested that individuals add additional locks to doors, while remaining aware of having all doors always locked.

	Annual Cost (20 years)	SR	Expected Cost
Locks	$4	34%	$12
Window Bars	$40	23%	$172
Shatter-proof windows	$120	23%	$521

Only the purchase of safety locks with an expected cost of $12 would provide value since the expected annual cost of break-in per household is $12.79 ($2,361 * .00542).

Tele-health (virtual office visits) - The cost of tele-health visits varies, depending on the cost of the visit the patient is requesting and their health plan design. General medical visits can be as low as $0 per visit with insurance and without insurance, general medical is $75 per visit. Tele-health services may boost access to a physician, but does it reduce overall health care spending. On average, a telehealth visit costs about $79, compared with about $146 for an office visit (Ibarra, 2017). However, Ibarra (2017) found that telehealth prompts patients to seek care for minor illnesses that often would not have induced them to visit a doctor's office. It was found that only 12% of telemedicine visits replaced an in-person provider visit, while 88% represented new demand. Researchers also estimated that annual spending for respiratory illnesses increased about $45 per tele-health user, compared with patients who did not take advantage of virtual consultations (Ibarra, 2017).

SUMMARY

Utilizing the technologies and devices presented in this study, a comparative cost effective analysis study to determine if the following technologies impacting home care would provide economic value in terms of cost benefit and cost effective analysis. It was found that five of the technologies provided economic value and two of them could provide economic value based on use, while one did not provide economic value.

Technology	Economic Value
Automated External Defibrillator	Potential
Amazon Products and services	Yes
Electronic Medical Records	Yes
Emergency Medical Service Membership	Potential
Fire Alarm Subscription Services	No

Fire Extinguishers	Yes
Fire Insurance Policies	No
Genome sequencing Tests	Yes
Helicopter Emergency Service	No
Home Fire Sprinklers	No
Home Security Systems	No
On-Line Pharmacies	Yes
Remote Patient Monitoring Devices	Yes
Robotic Surgery	Potential
Tele-health (virtual office visits)	Potential

CONCLUSION

The results of this study may potentially impact a variety of stakeholders who stand to benefit from the findings. A primary group would be individual patients who make decisions to home care treatment based on financial considerations. Private insurance companies could adjust reimbursement options to incentivize more patients to seek home care. Medical Centres could constitute another group of stakeholders as they are major providers of care and could integrate forward to increase profitability by reducing operating costs and develop new revenue streams by forward integration. The forward integrations could make them their own competitor, but if they don't integrate forward then surely new competitors will. The cost effectiveness of these technologies, often based on patient demand, is a major factor in determining the extent of their economic value. It's important to note that politicians who deliberate public policy formulation regarding national healthcare issues would be another important category of stakeholders. The Congressional Budget Office uses the comparative expected value approach to determine the cost-effectiveness of certain technologies and medical treatments as they develop healthcare policy. The methodology employed in this study is in line with those employed in similar studies within the literature. The results from the studies regarding the nine selected technologies were the subject of this study and contributed to a growing body of literature investigating the cost-benefit and cost-effectiveness.

According to Bera (2019) 85% of burglaries are committed by non-professionals. Therefore, some inexpensive products could provide value deterring a burglar without professional experience. Despite the annual costs of crime preventative measures, there is value in investing into some precautions such as a safe and door locks, but the most effective way to reduce costs would be to limit ownership of valuables, such as cash, jewelry, firearms, and electronics.

While this study concludes that fire insurance policies are not cost effective, they may be required by a home mortgage lender. In this instance, the required fire insurance protects the lender as much as the homeowner. It could be argued that this type of insurance is very cost effective for the lender as they are not paying for it. Additionally, home fire sprinklers may be required by some jurisdictions as part of building codes. While this study found them to not be cost effective, it may be necessary to install/maintain them when building a new home.

The methodology employed in this study is in line with those employed in similar studies within the literature. The results from the studies regarding the fourteen selected healthcare devices, services and technologies were the subject of this study and contributed to a growing body of literature investigating the cost-benefit and cost-effectiveness.

Further disaggregation of data may be needed for more in-depth analyses on the return on fire-prevention technology in apartment buildings and condominiums with multiple residential units. Fire spreading to multiple units is much easier and faster without fire-prevention equipment in a multi-unit building than it would from single unit home to home.

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