

**THE POTENTIAL BENEFITS
OF A WIRELESS ELECTROCARDIOGRAM
SYSTEM
FOR INPATIENT CARE**

PREPARED BY

THE LEWIN GROUP

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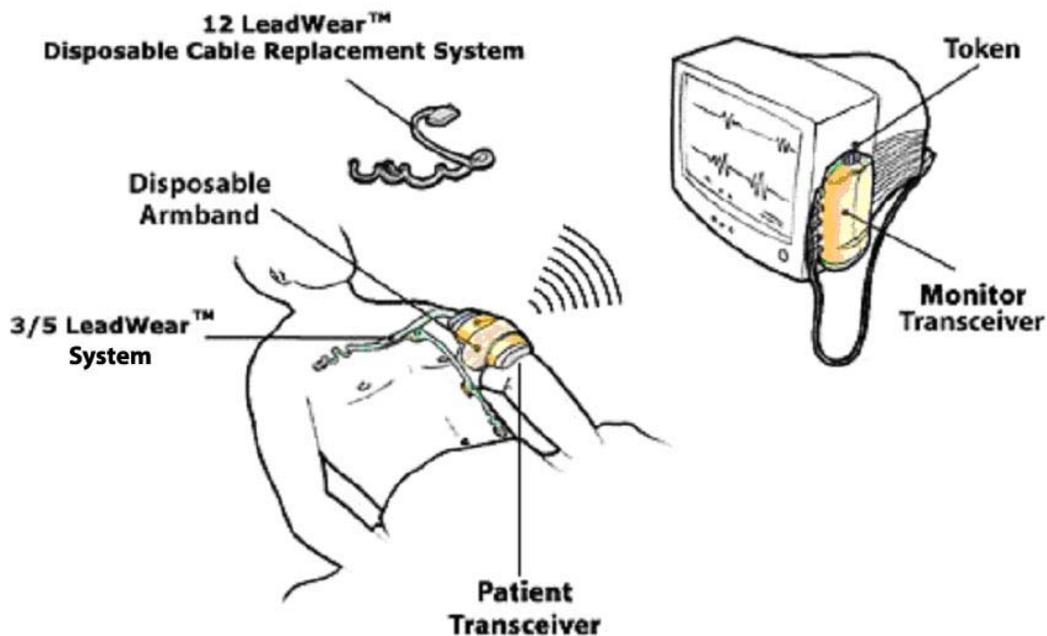
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EXECUTIVE SUMMARY

Currently, electrocardiogram (ECG) monitoring systems used in hospitals require patients to be physically connected to the ECG monitor via lead wires and electrodes for ECG monitoring of the heart during the hospital stay. Periodically, a 12-lead ECG is performed to evaluate acute events, monitor therapy, or to evaluate patients with cardiovascular disease. The ECG is produced by applying electrodes to various parts of the body. These electrodes are attached to wires and then to leads. As a result, existing wired ECG technology requires frequent lead wire and electrode attachments and detachments, equipment cleaning due to physical contact with patients, and frequent replacement of materials. All these activities carry materials cost and staff time implications for hospitals.

Recognizing the burden associated with current ECG technology, GMP Wireless Medicine, Inc. developed a wireless ECG system that, by using radiotransmission of data instead of wires, has the advantage of freeing, or untethering, the patient from the ECG monitor during his/her hospital stay. Because of the decreased need for electrode attachments and detachments as well as device cleaning, the GMP wireless system has the potential to reduce or eliminate some of the direct materials costs and nurse and other healthcare practitioner time associated with the current wired technology. This white paper serves to highlight the results of a study, sponsored by GMP Wireless Medicine, Inc. and carried out by The Lewin Group, undertaken to assess the potential value of the wireless electrocardiogram (WECCG) system to hospitals.

Components of the LifeSync® Wireless ECG System



In order to quantify direct material cost and personnel time savings as well as assess nurse satisfaction, The Lewin Group made site visits to four hospitals and two emergency medical service (EMS) units and conducted in-person and telephone interviews with hospital staff.

Information from these site visits/interviews was integrated along with data collected from other secondary data sources into a model that estimates the potential benefits of WECG use in hospitals, over the course of two representative (5-day) patient stays: 1) an acute myocardial infarction (AMI) patient, or an urgent heart attack admission; and 2) a coronary artery bypass grafting (CABG) patient, or an elective surgery admission.

The analysis suggests that direct material cost savings on electrodes, cleaning materials, lead wires and trunk cables are likely to occur for both AMI and CABG patients during a typical 5-day hospital stay (see figures below). In the baseline scenario, expected net materials cost savings are likely to total \$30 for AMI patients and \$21 for CABG patients. Altering assumptions related to electrode use and cleaning suggests that the net cost savings in direct materials from use of WECG could be as high as \$49 per AMI and \$34 per CABG patient stay.

Baseline Materials Cost Saving Scenario

| <u>Least Cost Saving WECG Scenario*</u> |
|--|
| • Net Savings on Electrodes \$26 AMI; \$17 CABG |
| • Net Savings on Cleaning Materials \$3 AMI; \$3 CABG |
| • Net Savings on Lead Wires & Trunk Cables \$1 AMI & CABG |
| <hr/> |
| Total Net Cost Savings \$30 AMI; \$21 CABG |

*Current cleaning practice;
Disposable snap-on electrodes

Greatest Materials Cost Saving Scenario

| <u>Greatest Cost Saving WECG Scenario*</u> |
|--|
| • Net Savings on Electrodes \$34 AMI; \$24 CABG |
| • Net Savings on Cleaning Materials \$14 AMI; \$9 CABG |
| • Net Savings on Lead Wires & Trunk Cables \$1 AMI & CABG |
| <hr/> |
| Total Net Cost Savings \$49 AMI; \$34 CABG |

*Recommended cleaning practice;
Repositionable snap-on electrodes in all units

In addition to direct material cost savings, use of WECG is also likely to reduce nurse time associated with ECG attachments/detachments, false alarms, artifacts etc. by approximately 3 hours per AMI and CABG patient stay. Although the decrease in nurse time associated with ECG is unlikely to result in direct cost savings to the hospital, nurses report increased job satisfaction as a likely outcome from allowing them to focus on patient care rather than ECG-related activities.

In summary, replacement of current wired ECG with a wireless system is likely to result in direct cost offsets and nurse time savings that should be weighed against system costs such as WECG disposables and transceivers. Recognizing that there is a link between improved job satisfaction and labor retention, hospitals should consider these nurse satisfaction endpoints when evaluating new technologies, especially given the current nursing shortage in the U.S.

CHAPTER 1: INTRODUCTION

Current Use of Wired ECG

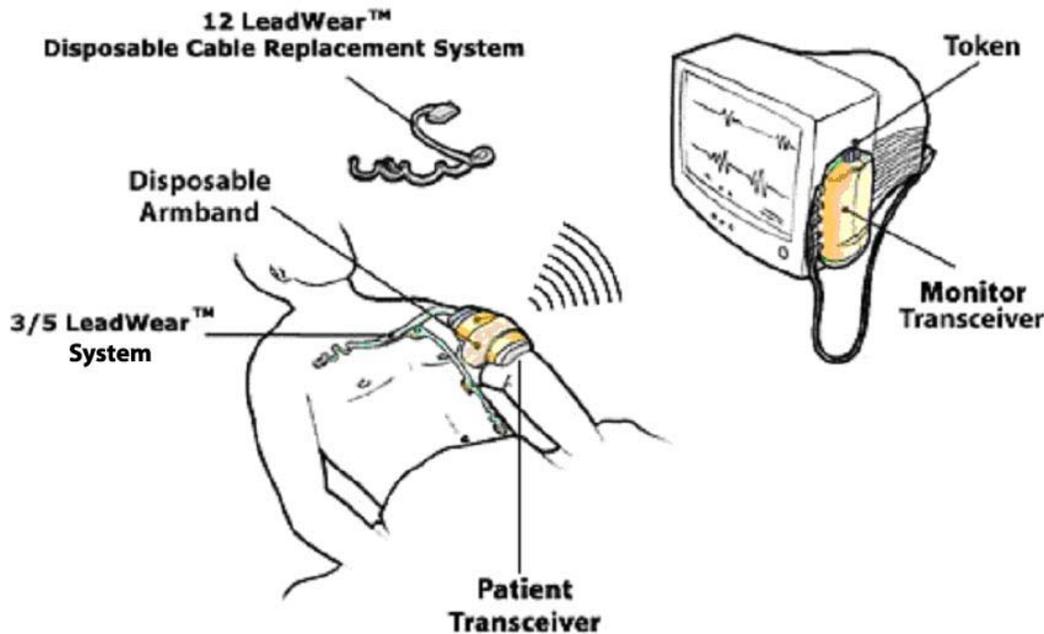
An electrocardiogram (ECG) provides a graphic tracing of the electric current generated by the heart muscle during a heartbeat, providing information on the condition and performance of the heart. Most electrocardiographic monitoring is performed by connecting patients to the ECG monitor via lead wires and electrodes. Electrodes are applied to various parts of the body. These electrodes are attached to wires, which are, in turn, attached to leads.

Because current wired ECG monitoring requires a patient to be attached to a monitor with wires, each time a patient is bathed, leaves the bed to go to the bathroom, or is transported to another department, these wires need to be detached and then reattached. Electrodes are frequently disposed of with each detachment, and new electrodes are then applied with the re-attachment. In addition to the staff time and materials costs associated with these attachments and detachments, the current wired ECG system is also associated with false alarms due to movement of the lead wires and to artifact due to inconsistent placement of electrodes. These false alarms require the nurse to attend to the patient, and frequently involve detachment and re-attachment of the wires. Finally, tethering the patient to the monitor may have an impact on patient comfort, lead to possible entanglement in the wires, and render nurse-assisted activities (e.g., bathing, changing linens, using bedpans) more complicated.

GMP Wireless Medicine, Inc. Electrocardiogram System (WECG)

GMP Wireless ECG technology has the advantage of freeing, or untethering, the patient from the ECG monitor during his/her hospital stay by using radiotransmission of data instead of wires. The WECG system consists of a 3/5 LeadWear™ Disposable Cable Replacement System that is worn on a patient's chest to perform continuous heart rate monitoring, a 12 lead LeadWear™ System to perform 12-lead ECG tests, a Patient Monitor Transceiver with a disposable Armband, and a Monitor Transceiver, which can be attached to the side of any ECG monitor (Figure 1). The design of the WECG LeadWear™ System allows for a pre-set but flexible configuration of electrode placement during ECG testing and monitoring. This configuration may allow for more accurate heart monitoring than current practice, where electrodes are placed individually on the patient's chest. With these components, WECG technology can be used for bedside or transport 3/5 lead monitoring and 12-lead ECG diagnostic or stress testing monitoring.

Figure 1. Components of the Wireless ECG Technology



The introduction of the WECG system may result in several potential benefits to the hospital. Hospitals that choose to convert to the WECG system could avoid direct medical costs (e.g., electrode use) as well as re-direct nurse time from patient ECG detachments/reattachments to more patient care oriented activities. In addition to improving patient comfort, this redirection of staff time is likely to have a positive impact on nurse job satisfaction, which has been shown to correlate to retention – an important issue for hospitals given the current nursing shortage.

Benefits of Hospital Conversion from Wired ECG to WECG

The objective of this study was to quantify the potential savings likely to occur when a hospital converts to WECG. As a step in quantifying these benefits, Lewin conducted a telephone survey of 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, DC including: 7 ICU nurses, 6 CCU nurses, 3 ER nurses, 3 cath lab nurses, 3 stress test nurses and technicians, 8 ECG technicians, and 4 EMS paramedics. Among other questions, respondents were asked to rate the likely benefits resulting from WECG use. Specifically, nurses, ECG technicians, and EMS paramedics rated the likelihood of various benefits resulting from WECG using a scale of 1 to 10, where 1 is “not at all likely” and 10 is “highly likely.” As seen in Figure 2, a reduction in stress test delay/waiting time, reduction in wire clutter, and uninterrupted monitoring were the highest-rated benefits of WECG. However, respondents thought that WECG is unlikely to capture diagnoses that are missed with current ECG monitoring, to shorten the time to ambulation, or to allow for more time for EMS calls (Figure 2).

Figure 2. Likelihood of Benefits Resulting from WECG

| <u>Highly Likely</u> | <u>Likely</u> | <u>Moderately Likely</u> | <u>Neutral to Unlikely</u> |
|--|---|--|---|
| <ul style="list-style-type: none"> • Reduce stress test delay/waiting time (9.3) • Reduce wire clutter (9.2) • Provide uninterrupted monitoring (9.0) | <ul style="list-style-type: none"> • Reduce time to attach/detach wires (8.7) • Eliminate need to clean wires/trunk cable (8.5) • Improve patient comfort (8.3) • Provide ease of equipment use (8.2) | <ul style="list-style-type: none"> • Improve patient satisfaction with hospital stay (7.7) • Reduce artifacts/false alarms (7.5) • Reduce infections from lead wire contact (7.3) | <ul style="list-style-type: none"> • Capture missed diagnosis/chest pain (6.6) • Shorten time to ambulation (5.3) • Allow for more EMS calls (3.0) |

*1=Not at all likely, 10=Highly likely

Source: The Lewin Group interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C

Although several benefits were rated as likely (e.g., an average rating of at least 7 out of 10), we chose to focus our analysis on three issues likely to result in tangible savings to the hospital, namely:

- Reduction in lead wire attachments/detachments (and associated electrode disposal) during patient transport, bathing, and other activities
- Elimination of the need for cleaning ECG lead wires and trunk cables following each patient use (i.e., wires/cables not in contact with the patient during WECG)
- Decrease in the number of false alarms due to the fixed configuration of a WECG patient wearable like the one illustrated in figure 1

To quantify the potential for avoiding material costs and personnel time as well as the potential improvement in nurse satisfaction resulting from attachments/detachments, lead wire/trunk cable cleaning, and false alarms/artifacts, The Lewin Group investigated use of current wired technology in performing 3/5 lead heart monitoring and 12-lead ECG testing across the following hospital departments: emergency room (ER), intensive care unit (ICU), coronary care unit (CCU), cath lab, stepdown unit, stress test lab, patient transport, and emergency medical service (EMS) units. To collect data on wired ECG as well as the potential benefits from WECG, we conducted site visits to four hospitals and two EMS units and in-person and telephone interviews with hospital staff. Based on the data collected, an interactive spreadsheet model was developed to synthesize information into a tool that estimates the direct material costs and staff time avoided when a hospital converts to WECG. See Appendix A for details on the study methodology and Appendix B for study findings on the resource utilization estimates (e.g., amount of materials used and amount of staff time required for certain activities) used to develop the analysis.

CHAPTER 2: POTENTIAL FOR HOSPITAL SAVINGS FROM CONVERSION TO WECG

The potential for benefits accruing to a wireless ECG system can be broadly categorized into two areas: 1) direct materials and 2) staff time (i.e., indirect costs). This study estimates both direct material cost and staff time savings to the hospital through two representative cardiac inpatient stays: a) an acute myocardial infarction (AMI) patient stay, which is an urgent care situation; and b) a coronary artery bypass grafting (CABG) patient stay, which is an elective care situation.

Potential Direct Material Cost Savings

Conversion from wired ECG to wireless ECG has the potential to reduce direct material costs for electrodes, cleaning materials, and lead wires and trunk cables. The potential for savings in each of these areas is described below.

Potential Electrode Cost Savings

As described in the overview of wired ECG, current practice is to discard electrodes following lead wire removal during transport, bathing, and other activities. Because a WECG system eliminates the need for frequent attachment/detachment, electrodes could potentially be used for a longer period of time. Savings under different scenarios of electrode type (i.e., repositionable snap-on for 3/5 lead monitoring and 12 lead ECG monitoring vs. repositionable snap-on for both) and duration of use (entire hospital stay vs. all settings prior to stepdown) were explored for each of the representative AMI and CABG patient stays (Figure 3).

Figure 3. Wired ECG vs. WECG Electrode Scenarios

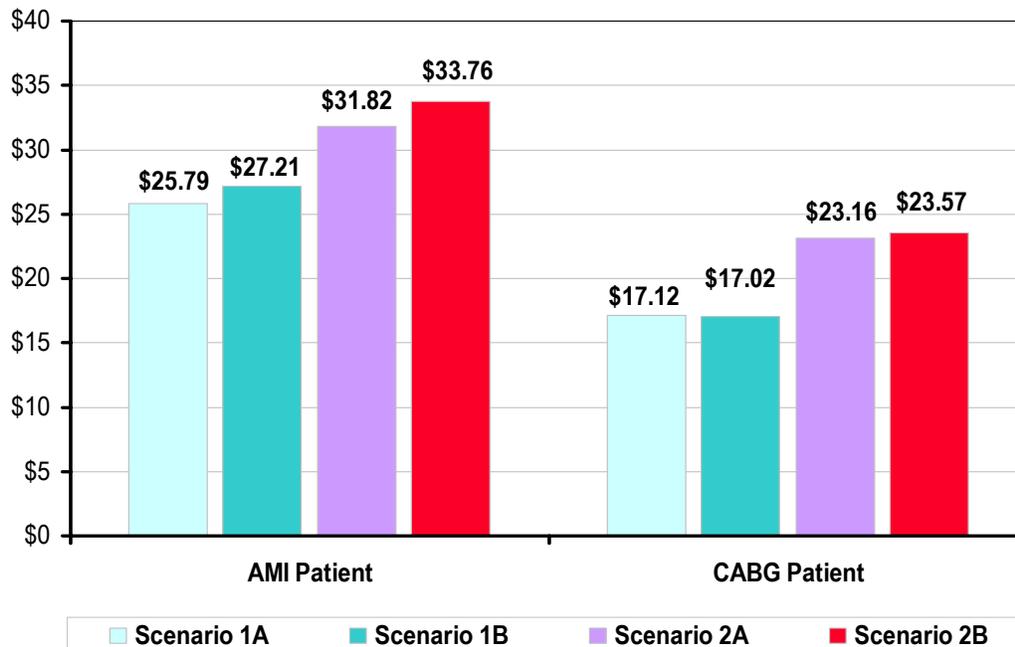
| | Current wired ECG | WECG Scenario 1A | WECG Scenario 1B | WECG Scenario 2A | WECG Scenario 2B |
|--|---------------------------------|---|----------------------------------|---|----------------------------------|
| Electrode Type | Disposable Snap-on & Tab | Repositionable Snap-on (CW) & Disposable Tab (DW) | Repositionable Snap-on (CW & DW) | Repositionable Snap-on (CW) & Disposable Tab (DW) | Repositionable Snap-on (CW & DW) |
| Electrode Replacement Rate | Each use | Snap-on: 3 days Tab: Each use | 3 days | Snap-on: 3 days Tab: Each use | 3 days |
| Duration of Monitoring | Entire patient stay | All settings prior to Stepdown | All settings prior to Stepdown | Entire patient stay | Entire patient stay |
| Number of Snap-On Electrodes Used | 140 (AMI) 109 (CABG) | 39 (AMI) 39 (CABG) | 44 (AMI) 45 (CABG) | 13 (AMI) 14 (CABG) | 17 (AMI) 17 (CABG) |
| Number of Tab Electrodes Used | 128 (AMI) 82 (CABG) | 74 (AMI) 51 (CABG) | 20 (AMI) 20 (CABG) | 64 (AMI) 41 (CABG) | 0 (AMI) 0 (CABG) |
| Cost of Electrodes Used | \$39.87 (AMI) \$29.99 (CABG) | \$14.08 (AMI) \$12.86 (CABG) | \$12.67 (AMI) \$12.97 (CABG) | \$8.05 (AMI) \$6.83 (CABG) | \$6.11 (AMI) \$6.41 (CABG) |

Scenarios 1A and 1B reflect WECG use only in settings prior to the Stepdown unit and stress test lab – where wired ECG is assumed to be used
 Scenarios 2A and 2B reflect WECG use throughout the hospital stay, assuming that WECG is telemetry adaptable in the Stepdown unit
 CW – WECG 3/5 lead Wearable; AMI – Acute Myocardial Infarction patient stay (urgent admission)
 DW – WECG Wearable; CABG – Coronary Artery Bypass Grafting patient stay (elective admission)

As seen in Figure 3, compared with wired ECG, WECG in all four scenarios has the potential to reduce the number of electrodes used during a hospital stay, resulting in net electrode cost savings to the hospital. Figure 4 displays the net electrode cost savings generated from a conversion to WECG.

According to the analysis, per patient savings in electrodes could range between \$26 and \$34 for AMI and \$17 and \$24 for CABG.

Figure 4. Net Electrode Cost Savings



Scenarios 1A and 1B reflect WECG use only in settings prior to the Stepdown unit and stress test lab – where wired ECG is assumed to be used
 Scenarios 2A and 2B reflect WECG use throughout the hospital stay, assuming that WECG is telemetry adaptable in the Stepdown unit

As seen in Figures 3 and 4, savings are likely to be greatest when the WECG is paired with repositionable electrodes that are replaced less frequently than current practice (i.e., despite higher unit costs) and when WECG is telemetry adaptable and used seamlessly throughout the entire patient stay.

Potential Cleaning Materials Cost Savings

Direct material cost savings in cleaning materials is modeled based on the frequency of cleaning and the number of alcohol swabs used to clean ECG equipment as reported by nurses. As presented in Appendix B, 3/5 lead bedside monitor lead wires and trunk cables are cleaned once per patient stay with an average of 2.7 alcohol wipes used per cleaning. 12-lead ECG monitor lead wires and trunk cables are generally cleaned every 2 days in the ICU/CCU, every 2 weeks in the ER, and after every test in the stress test lab with an average of 6.2 alcohol wipes used per cleaning. The stepdown unit was not included in this analysis because the monitors used in the stepdown unit are usually cleaned centrally in the ECG department; additional cost savings from cleaning monitors used in the stepdown unit would be minimal.

Cleaning of transport monitor lead wires and trunk cables is also not included in the analysis due to the lack of cleaning and the lack of cleaning observed in hospitals. Lastly, any materials that may be necessary for cleaning WECG's Patient Transceivers are also not included in this analysis.

Based on these assumptions, the analysis suggests that the net cleaning materials cost savings would be approximately \$3.45 for an AMI patient and \$3.21 for a typical CABG patient stay.

A subsequent analysis was performed with regards to savings accrual if a hospital-recommended cleaning protocol is followed. The hospital-recommended cleaning protocol was assumed to be the following: a recommended frequency of lead wire and trunk cable cleaning would be performed in the ER, ICU/CCU and cath lab following each 12-lead ECG test; a recommended protocol for cleaning would be followed for 3/5 lead monitor lead wires and trunk cables (once per patient stay in each department) and for cleaning for transport monitor lead wires and trunk cables (once every 2 transports). Again, the analysis assumes no lead wire, trunk cable, or Patient Transceiver cleaning is necessary with WECG.

The net cleaning materials cost savings if a recommended protocol of cleaning is followed would be approximately \$14.33 for an AMI patient and \$9.17 for a typical CABG patient stay.

Potential Lead Wires / Trunk Cable Cost Savings

Since a patient is untethered to the monitor with the WECG technology, it has the potential to reduce the ‘wear and tear’ caused to lead wires and trunk cables used during 3/5 lead monitoring. Additional cost savings of 12-lead ECG wires and trunk cable over a 5-day patient stay would be minimal due to equipment sharing across numerous patients.

As presented in Appendix B, nurses and ECG technicians estimated that lead wires and trunk cables would last longer with WECG than with current wired ECG. lead wires would last 2.6 times longer with WECG than with current wired ECG (1.7 years versus 7 months). Similarly, trunk cables would last 2.4 times longer with WECG than with current ECG (2.9 years versus 1.2 years). Based on these assumptions, hospitals would realize savings over the course of a typical 5-day patient stay in the hospital.

The net lead wire and trunk cable cost savings per patient would be approximately \$0.67 for one lead wire set (i.e., 5 wires) and \$0.35 for one trunk cable used with 3/5 lead monitoring.

Summary of Potential Direct Materials Cost Savings

Figure 5 and Figure 6 summarize estimated direct material costs related to electrodes, cleaning materials, and lead wires/trunk cables avoided through conversion to WECG.

As seen in the figures, the savings per an AMI patient stay could total \$30 or range as high as \$49 depending on hospital practices related to electrode use, cleaning, and adaptability with telemetry. Similarly, direct material cost savings are projected to total between \$21 and \$34 per CABG patient stay.

**Figure 5. WECG Materials Cost Savings
Baseline Scenario**

| <u>Least Cost Saving WECG Scenario*</u> |
|---|
| • Net Savings on Electrodes \$26 AMI; \$17 CABG |
| • Net Savings on Cleaning Materials \$3 AMI; \$3 CABG |
| • Net Savings on Lead Wires & Trunk Cable \$1 AMI & CABG |
| Total Net Cost Savings \$30 AMI; \$21 CABG |

*Current cleaning practice;
Disposable snap-on electrodes

**Figure 6. WECG Materials Cost Savings
Greatest Savings Scenario**

| <u>Greatest Cost Saving WECG Scenario*</u> |
|---|
| • Net Savings on Electrodes \$34 AMI; \$24 CABG |
| • Net Savings on Cleaning Materials \$14 AMI; \$9 CABG |
| • Net Savings on Lead Wires & Trunk Cable \$1 AMI & CABG |
| Total Net Cost Savings \$49 AMI; \$34 CABG |

*Recommended cleaning practice;
Repositionable snap-on electrodes in all units

Potential for Reallocation of Staff Time

Although conversion to WECG is unlikely to result in reduction in nursing staff, it does offer the potential for reallocation of staff time to patient care and other important activities. When asked what other activities or duties they would perform with potential time savings, respondents mentioned they would: (1) provide more patient care, (2) complete more chart work, (3) spend more time to track and administer medications, (4) perform more patient education, and (5) spend more time to talk to families.

In this study, we estimate the potential for staff time savings through reduction or elimination of:

- Lead wire attachments and detachments during the following activities: entry into and departure from departments, ancillary transports, baths, 12-lead ECG tests, and stress tests
- Lead wires and trunk cable cleaning
- False alarms
- Artifact

The frequency of attachment/detachment as well as the average time spent attaching/reattaching patients, cleaning lead wires and trunk cables, responding to false alarms and correcting artifacts is detailed in Appendix B.

Based on these assumptions, we calculate that the overall potential for nurse time savings with WECG is approximately 185 minutes (or 3.1 hours) per patient stay for an AMI patient. Similarly, overall potential for nurse time savings for a CABG patient is 170 minutes (or 2.9 hours) per stay.

Because approximately two-thirds of the 3 hour savings potential in AMI and CABG patients is due to WECG's potential to reduce false alarms and artifact, we validated our observed frequency of false alarms during the four site visits through the nurse telephone interviews. Interestingly, the nurse reported frequency of false alarms was almost 4 times greater than the observed frequency. We hypothesize that this large difference between the observed number of false alarms and nurse-reported numbers stems from a large perceived burden associated with false alarms. Calculating the overall potential for staff time savings based on the nurse estimates of the frequency of false alarms results in a savings of approximately 7 hours per patient stay.

The actual amount of staff time that could perhaps be redirected towards other activities following adoption of WECG likely falls somewhere in between these estimates, namely 3 to 7 hours per patient stay. As mentioned above, although this time savings is unlikely to result in an FTE reduction, nurses will be able to redirect their time towards providing more patient/family care and completing administrative tasks during the shift. The findings in Chapter 3 highlight the value of these nurse time savings on job satisfaction.

CHAPTER 3: POTENTIAL IMPACT ON NURSE JOB SATISFACTION, RETENTION, AND QUALITY OF CARE

Impact of Hospital Conversion to WECG on Nurse Job Satisfaction

In order to determine the potential benefits from WECG, nurses at the 4 study sites were asked to respond to a written survey about potential benefits of WECG. The response rate to the mailed survey was low, however, due to busy schedules. In order to collect more detailed data, supplementary one-on-one telephone interviews were conducted with 7 ICU nurses, 6 CCU nurses, 3 ER nurses, 3 cath lab nurses, 3 stress test nurses and technicians, 8 ECG technicians, and 4 EMS paramedics. Among other questions, nurses, ECG technicians, and EMS paramedics were asked to rate the impact of potential WECG benefits on their job satisfaction (see Table 1).

Table 1. Impact of WECG Benefits on Job Satisfaction

| Potential Benefit | Impact on Job Satisfaction* |
|---------------------------------------|-----------------------------|
| Reduce stress test delay/waiting time | 9.0 |
| Reduce time to attach/detach wires | 8.9 |
| Reduce wire clutter | 8.7 |
| Provide uninterrupted monitoring | 8.4 |
| Provide ease of equipment use | 8.4 |
| Reduce artifacts/false alarms | 8.4 |
| Improve patient satisfaction | 8.3 |
| Staff time savings | 8.2 |
| Eliminate need to clean wires/cables | 8.2 |
| Improve patient comfort | 8.2 |
| Reduce infections from lead wire | 7.9 |
| Capture missed diagnosis/chest pain | 7.0 |
| Shorten time to ambulation | 6.8 |
| Allow for more EMS calls | 6.0 |

*1=No improvement at all, 10=Extreme improvement

Source: The Lewin Group interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C.

As seen in Table 1, nurses would derive job satisfaction if one or more of the 14 potential benefits of WECG were realized. Benefits that would have the most significant impact on job satisfaction include: reduction in stress test delays/waiting time, reduction in time to attach/detach lead wires, and reduction in wire clutter. When asked specifically about the impact of time savings on job satisfaction, hospital personnel rated this element an average of 8.2 on a 10 point scale.

WECG Implications for Nurse Job Satisfaction, Retention, and Quality of Care

As presented in this study, hospital conversion to WECG has the potential to avoid direct material costs and to improve working conditions for nurses. Specifically, a reduction in the frequency of routine lead wire attachments/detachments and false alarms made possible by WECG would give nurses more time to provide more care, track and administer medications, perform patient education, talk to families, and complete more chart work. Nurses indicated that time for these other duties would favorably impact job satisfaction--an important outcome given the high level of nurse dissatisfaction in hospitals today.

For example, results from a recent study suggest that as many as 40 percent of nurses currently working reported being dissatisfied with their jobs (Aiken, Clarke, Sloan 2001). Much of this dissatisfaction stems from nurses being overworked and overburdened, often with tasks that were once the responsibility of less skilled workers. As a result of the current working conditions in hospitals, nurses report that they are spending less time taking care of increasingly ill patients (Needleman 2002).

Ultimately, nurse job dissatisfaction manifests itself in many ways: high turnover and replacement costs, reduced quality of care, increased patient care costs, and lowered bottom lines (JCAHO 2002). The link between job dissatisfaction and staff turnover is well-established (Johnson 1997; Irvine and Evans 1995; Cavanagh 1989; Weisman, Alexander, and Chase 1981). At no time has nurse turnover been a bigger issue than the present. The current 26 percent turnover rate among nurses is the highest in decades (Weintraub 2002). In a recent study, 22 percent of nurses reported that they were planning to leave their jobs in the next year (Aiken, Clarke, Sloan 2001).

Nursing turnover carries high costs. Fifty-six percent (56%) of hospitals report that they are using agency or traveling nurses, at a considerable expense, to fill vacancies. The salary differential between an employee and an agency nurse can range from 50 to 100 percent, with the highest difference in critical care, operating room, and emergency departments (State of Connecticut 2001). Hospitals have resorted to offering sign-on bonuses of \$15,000 or more to recruit nurses (Weintraub 2002; Janofsky 2002). In fact, a report by the Voluntary Hospitals of America (VHA) concludes that it costs approximately 100 percent of a nurse's salary to fill a vacated nursing position. Other studies arrive at a similar cost estimate for nurse recruiting – an average of \$46,000 for a medical/surgical nurse and \$64,000 for a critical care nurse (Kosel and Olivo 2002).

The costs of recruitment and re-staffing aside, high turnover is associated with higher costs per patient discharge. The VHA report determined that organizations with higher turnover rates—21 percent or more—had a 36 percent higher cost per discharge (and lower profitability) than hospitals with low turnover rates of 12 percent or less. Specifically, low turnover organizations averaged a 23 percent return on assets as compared to a 17 percent return for high turnover organizations (Kosel and Olivo 2002).

More importantly, high nurse turnover negatively impacts the quality of care provided. Needleman et al. (2002) found that the greater number of hours of care provided by registered nurses, the lower the length of stay and other adverse outcomes including: urinary tract infection, upper gastrointestinal bleeding, pneumonia, shock, cardiac arrests, and “failure to rescue”. Similarly, another study concluded that low turnover hospitals (at rates under 12%) had lower mortality scores as well as lower lengths of stay compared with hospitals with turnover rates that exceeded 22 percent (Kosel and Olivo 2002).

Given the current nursing crisis and a bleak outlook for improved staffing, significant improvements in the day-to-day tasks of nurses are enlightened investments.

As the VHA report suggests, there is a strong business case for creating a culture of retention. Monies spent on recruitment and replacement could obviously be better spent on improving the work environment for nurses.

CHAPTER 4: CAVEATS AND LIMITATIONS TO THE STUDY

This white paper highlights the potential for avoidance of direct material cost and nurse staff time through conversion from the current wired ECG technology to a wireless electrocardiogram (WECG) system. As such, the study focused on the potential for savings based on differences in attachment/reattachment rates, lead wire/trunk cable cleaning, and false alarms. The study was not designed to make full estimates of the entire costs and benefit profiles for both systems.

The estimates developed by this study were for U.S. hospitals, in general. Actual values of these estimated savings may vary by hospital based on differences in existing hospital technology, processes, and staffing. For example, WECG is likely to be particularly beneficial for less technologically advanced hospitals (i.e., those without a hospital-wide telemetry system). It is also important to note that variation in hospital purchasing protocols could also impact the potential savings from WECG. Hospitals that purchase on a more centralized basis (i.e., as opposed to department by department) will be more likely to realize the full potential of WECG (e.g., 3/5 lead wear throughout the entire hospital stay, allowing for seamless patient transport).

Some changes in hospital nursing practice may be necessary to realize the greatest savings estimated by this study. Although potential direct cost savings are greatest with repositionable electrodes, maximum direct electrode cost savings will be realized only if staff change their existing protocol of discarding electrodes after each detachment/reattachment. The potential for direct materials savings are sensitive to both disposable or repositionable electrodes after each use as well as unexpected reasons for electrode removal (i.e., contact with patient clothing or blankets, electrodes dropped on floor, contact with excess bodily fluid/tissue in cath lab/OR, etc.). In addition to changes in protocol related to electrodes, adherence to existing hospital protocols on the frequency of equipment cleaning is also necessary to realize the full potential savings from WECG conversion.

As described in this White Paper, potential nurse time savings with WECG technology during a 5-day patient stay is approximately 3 hours. Thus, this time savings is unlikely to result in an FTE decrease, particularly if the hospital is already operating at minimum nurse-to-patient staff ratios. Rather, nurse time formerly spent on replacing electrodes, attaching and detaching lead wires, and responding to false alarms will be reallocated to other activities (e.g., charting, administering medications, more patient care), likely resulting in increased nurse and patient satisfaction.

Finally, because the data used to generate this model were based on direct observation at 4 hospital study sites and one-on-one telephone interviews with 34 providers, a prospective outcomes trial would be required to provide conclusive evidence of the savings potential from conversion to WECG. This outcomes study would not only provide more conclusive information on key drivers of direct material cost and nurse time savings (e.g., the frequency of false alarms and artifacts), but also facilitate the measurement of additional potential WECG benefits such as a reduction in time to patient ambulation or a decrease in cross-contamination of hospital-acquired bacteria.

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APPENDIX A: STUDY METHODS

The study was carried out in four phases.

Phase I: Exploratory Telephone Interviews

To gain a better perspective on current ECG practice and the potential benefits of WECG, 22 one-hour telephone interviews were conducted with various stakeholders including cardiologists, nurses, ECG technicians, biomedical engineers, purchasing and supply department personnel, and EMS paramedics. The exploratory interviews focused on better understanding the processes associated with wired ECG monitoring, typical cardiac patient flow through the hospital and use of ECG by departments, estimated time utilization associated with lead wire attachments and detachments, and perceived advantages/disadvantages of wired ECG versus WECG. Interview results were instrumental in shaping subsequent methods for detailed in-hospital data collection.

Phase II: Plan for Data Collection and Analysis

The data collection and analysis plan incorporated the following data components: frequency of events associated with the use of wired ECG equipment (i.e., lead wire attachment/detachment, electrode replacement, cleaning of lead wires, replacement of lead wires and trunk cables); cost of materials associated with wired ECG; staff time requirements associated with wired ECG; and nurse perceptions of wired ECG and WECG. The plan also described the benefit model and sensitivity analyses to be performed.

Phase III: Data Collection (Field Work)

Data collection occurred via observation, staff interviews, and patient chart reviews at four hospital study sites (a large hospital in the Northeast; a large hospital in the Southwest; two large hospitals in the Mid-Atlantic Region) and two EMS units in the Washington, DC metropolitan area. Data collected via direct observation included the timing of lead wire attachments and detachments for 3/5 lead bedside, transport, and 12-lead ECG testing; frequency of 3/5 lead ECG monitor false alarms; and the number of leads/electrodes used with 3/5 lead monitoring and 12-lead ECG testing. Data collected via patient chart review included patient flow throughout the hospital and the frequency of 12-lead ECG tests for a sample of cardiac patients. In addition, 34 supplemental one-on-one telephone interviews were conducted with ICU, CCU, ER, Stress Test and Cath Lab nurses; ECG technicians; and paramedics across several hospitals in Los Angeles, Philadelphia, and Washington, D.C. Data collected through these interviews included: patient flow throughout the hospital and length of stay in each department; frequency of 12-lead ECG tests and artifacts; frequency of baths, ancillary transports, and 3/5 lead monitoring false alarms; and estimated staff time involved in responding to false alarms and artifacts.

Phase IV: WECG Benefits Analysis (Modeling)

Data synthesis culminated in a spreadsheet model of potential benefits/value of the WECG technology.

The interactive model estimates the resources (direct material cost and staff time) involved in performing 3/5 lead monitoring and 12-lead ECG testing for the wired ECG situation and estimates the potential for

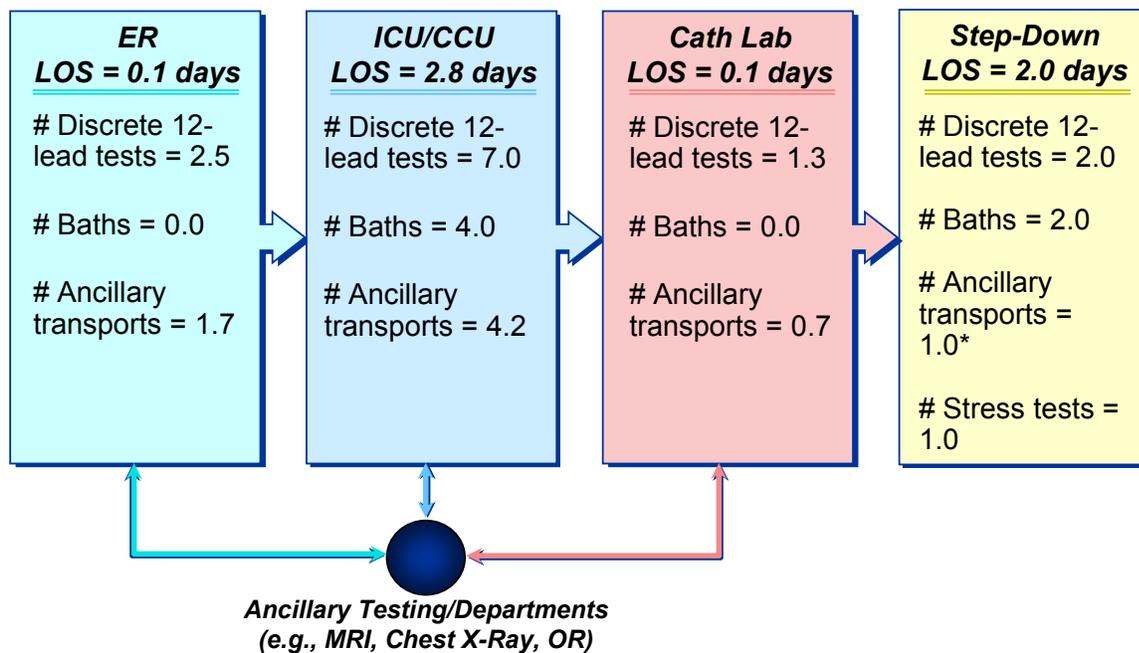
avoiding resource use through conversion to the WECG system. The analysis of potential benefits/value of WECG technology was performed from a hospital perspective for two representative cardiac patient stays: 1) acute myocardial infarction patient (“urgent” profile); and 2) coronary artery bypass grafting patient (“elective” profile). Model inputs included: direct materials use and cost with wired ECG vs. WECG and staff time utilization with wired ECG vs. WECG. Costs are estimated by multiplying the frequency of the ECG activities requiring resource utilization by the unit cost of that resource. Model outputs are potential direct material cost (e.g., electrodes, alcohol wipes, lead wires, and trunk cables) savings to the hospital and potential indirect savings in staff time. Other benefits, such as nurse job satisfaction, patient satisfaction, and reduced time to patient ambulation are presented in a qualitative manner.

APPENDIX B: STUDY FINDINGS ON COMPONENTS USED FOR ANALYSIS

Patient Profiles

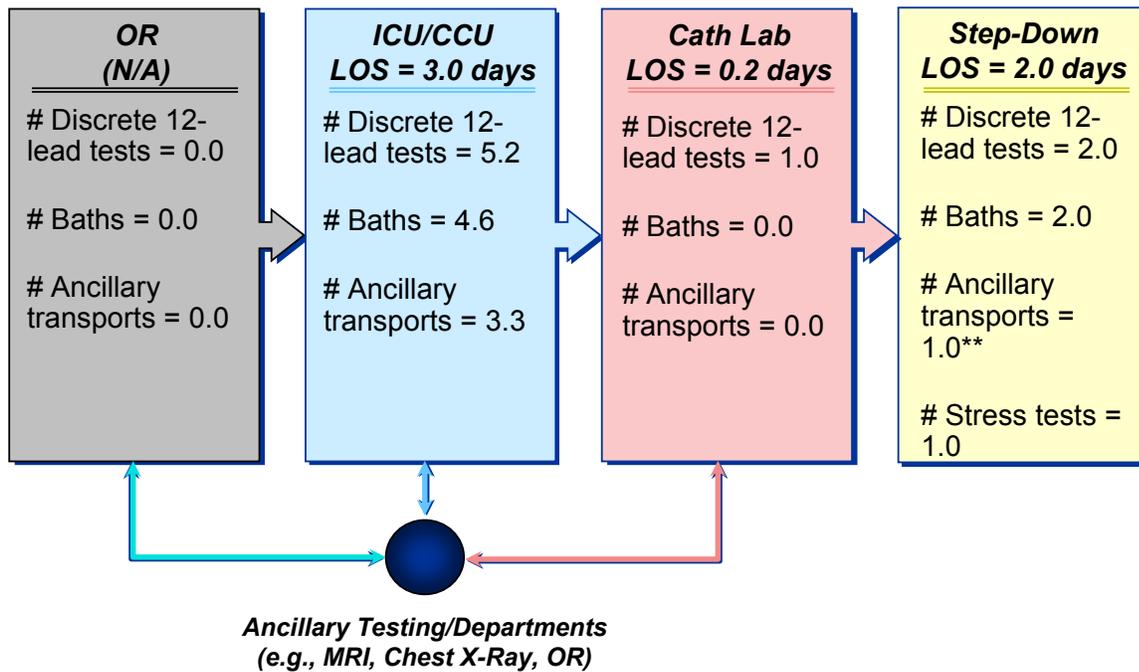
Two common cardiac patient profiles were constructed for the WECG benefit analysis: (1) “urgent” profile: Acute Myocardial Infarction (AMI) and (2) “elective” profile: Coronary Artery Bypass Graft (CABG). Patient profiles were constructed using various data sources, including direct observations made during visits to study sites; patient chart reviews; and exploratory and supplementary interviews with nurses, ECG technicians, and EMS paramedics. The information gathered through these methods was validated via analysis of hospital utilization data from the 1999 Nationwide Inpatient Sample (NIS) database. The total length of stay in the hospital and department-specific lengths of stay in the ER, ICU/CCU, and Cath Lab were obtained from supplementary interviews. Length of stay in the Stepdown unit for both patient profiles was derived by subtracting the lengths of stay in the ER, ICU/CCU, and Cath Lab from the total hospital stay. The patient flow through the hospital, together with the frequencies of ECG activities, is described for the representative AMI patient in Figure B1, and for the representative CABG patient in Figure B2.

Figure B1. Cardiac Patient Profile 1: AMI Patient Flow through Hospital



Source: The Lewin Group in-hospital data collection and interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C.

Figure B2. Cardiac Patient Profile 2: CABG Patient Flow through Hospital



Source: The Lewin Group in-hospital data collection and interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C.

Direct Materials Costs

Potential savings from disposable materials were calculated for electrodes, alcohol/antiseptic cleaning supplies, and lead wires/trunk cables. The potential reduction in use of other disposable materials (e.g., bedpans) was investigated but did not yield any significant savings. Material use (i.e., frequency and amount) was estimated via observation at study sites and collected through supplementary interviews. Costs were taken from list prices in a hospital supply catalog (Pearson Surgical Supply Catalog 2000-2001) and from in-person interviews with study site hospital staff in biomedical engineering and materials management. Materials prices did not include discounts because health economic convention is to generate models based on list prices. To the extent that hospitals are realizing deep discounts on materials purchases, the potential direct material cost savings from WECG may be dampened.

Electrodes

The analysis for electrodes cost savings involves snap-on electrodes and tab electrodes.¹ Assumed duration of use was up to one day for disposable snap-on electrodes (e.g., 3M Red Dot Foam Electrode) and for tab electrodes (e.g., 3M Red Dot Resting Electrode), and up to three days for repositionable snap-on electrodes (e.g., 3M Red Dot Repositionable Electrode).

The following assumptions regarding the use of electrodes with wired ECG were included in the model:

¹ Results in Figures 2 through 6 in Chapter 2 reflect analysis of 3M Red Dot Foam (snap-on) Electrode at \$0.23/electrode, 3M Red Dot Repositionable (snap-on) Electrode at \$0.37/electrode, and 3M Red Dot Resting (tab) Electrode at \$0.06/electrode.

- 10 tab electrodes are used for a 12-lead ECG
- 10 snap-on electrodes are used for a stress test
- 5 snap-on electrodes are used for 3/5 lead bedside monitoring
- 4 snap-on electrodes are used for 3/5 lead transport monitoring.

The following assumptions regarding the use of electrodes with WECG were included in the model:

- 5 snap-on electrodes are used for the 3/5 LeadWear™ System
- 5 snap-on or 5 tab electrodes are used for the 3/5 LeadWear™ System
- 5 snap-on electrodes are used for transport with the 12 LeadWear™ System
- For stress tests, 10 snap-on electrodes are used with both LeadWear™ System or 5 snap-on electrodes are used with the 3/5 LeadWear™ System and 5 tab electrodes are used with the 12 LeadWear™ System

Cleaning Materials

The analysis presents results for potential cleaning materials savings using PDI® Sterile Wipes with saline at \$0.15/wipe. Nurses and ECG technicians reported the frequency of and materials used per patient stay for lead wires and trunk cable cleaning:

- Continuous bedside monitor lead wire and trunk cable are cleaned once per patient stay in each department
 - 2.7 wipes are used per cleaning
- 12-lead monitor/stress test lead wire and trunk cables are cleaned every two days in the ER, ICU/CCU and Cath Lab, and once every test in the Stress test lab
 - 6.2 wipes are used per cleaning

The analysis assumes that WECG eliminates the need to clean lead wires and trunk cables. Any materials that may be necessary for cleaning WECG's Patient Transceiver were not included in this analysis.

Lead Wires and Trunk Cables

The costs of lead wires (\$15.00 per lead wire) and trunk cables (\$87.25 per trunk cable; range of \$50 to \$125) were obtained from in-person interviews with hospital staff in biomedical engineering and materials management departments. During supplementary interviews, nurses and ECG technicians reported the durability of these materials:

- A typical lead wire set lasts approximately 0.6 years and a trunk cable lasts approximately 1.2 years with wired ECG

- Nurses and ECG technicians estimated that a typical lead wire set might last 2.6 times longer, or 1.7 years, and that a trunk cable might last 2.4 times longer, or 2.9 years, if used with WECG rather than wired ECG

Staff Time (Indirect Costs)

Data on staff time utilization with wired ECG were collected by shadowing staff in hospital and pre-hospital settings. Nurses, 12-lead ECG technicians, and EMS paramedics were shadowed in the following settings of care: ER, ICU, CCU, Cath lab, Stress Test lab, PACU, Stepdown, Transport, and EMS. Measurements were taken on the frequency and timing of wired ECG activities that would be potentially eliminated or reduced with the WECG system in hospitals. Potential differences in staff time spent between wired ECG and WECG focus on the following activities: elimination of patient lead wire attachments/detachments (from continuous and 12-lead ECG monitors), elimination of time spent cleaning lead wires and trunk cables, and potential reduction in the frequency of and time spent responding to false alarms and artifacts.

Lead Wire Attachments/Detachments

Frequency

The analysis assumes that the WECG system would eliminate staff time spent attaching and detaching lead wires during current wired ECG monitoring. The frequency of wired ECG lead wire attachments and detachments was obtained via direct observation and supplementary interviews. Continuous ECG monitor lead wire attachments/detachments occur upon: entry into departments, departure from departments, transport for ancillary testing, and patient bathing. From supplementary interviews, the frequency of attachments/detachments was obtained for these various activities:

- Ancillary testing was reported to occur 1.7 times per stay in ER for an AMI patient; 1.5 times per day in ICU/CCU for an AMI patient and 1.1 times per day for a CABG patient; and 0.7 times per day in Cath lab for an AMI patient only
- Bathing was reported to occur 1.4 times per day in the ICU/CCU for an AMI patient and 1.5 times per day in the ICU/CCU for a CABG patient; 1 time per day in the Stepdown unit; typically no baths were reported to occur in the ER, Cath lab, or Stress test lab

12-lead ECG monitor lead wire attachment/detachment occurs upon every 12-lead ECG test and stress test performed. The number of total lead wire attachments/detachments for current wired ECG is summarized in Table B1 for the representative AMI patient and in Table B2 for the representative CABG patient.

Table B1. Summary of ECG Events Requiring Staff Attention in Current Wired Technology – AMI Patient Stay

| | ER | ICU/CCU | Cath Lab | Step-down | Stress Test | Total |
|--|------|---------|----------|-----------|-------------|-------------|
| LOS (days) | 0.1 | 2.8 | 0.1 | 2.0 | N/A | 5.0 |
| Continuous ECG Monitoring Event Frequencies | | | | | | |
| Admission (detach from transport) | 1.0* | 2.0 | 2.0 | 1.0* | 1.0* | 7.0 |
| Baths per LOS | 0.0 | 8.0 | 0.0 | N/A | N/A | 8.0 |
| Ancillary transports per LOS | 1.7 | 4.2 | 0.7 | 1.0 | N/A | 7.6 |
| False Alarms per LOS [†] | 0.8 | 30.1 | 1.1 | N/A | N/A | 31.9 |
| Depart (onto transport) | 1.0 | 1.0 | 1.0 | 1.0** | 1.0* | 5.0 |
| 12-lead/Stress Test Event Frequencies | | | | | | |
| 12-lead tests per LOS | 2.5 | 6.9 | 1.3 | 2.0 | 1.0 | 13.7 |
| 12-lead artifacts per LOS [‡] | 0.8 | 2.0 | 0.4 | N/A | 0.8 | 4.0 |
| Total # of Events | | | | | | 77.2 |

*Most events require both an attachment and detachment except those upon first entry to the ER (one attachment; detachment is from EMS) or departments with no hard-wired continuous monitoring (Stepdown unit and Stress Test lab).

**One detachment upon hospital discharge

†10.8 observed false alarms per patient per 24 hour for all departments

‡0.30 artifacts per 12-lead ECG in ER, ICU/CCU, Cath lab; 0.73 artifacts per 12-lead ECG in stress test lab

Source: The Lewin Group in-hospital data collection and interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C.

Table B2. Summary of ECG Events Requiring Staff Attention in Current Wired Technology – CABG Patient Stay

| | OR | ICU/CCU | Cath Lab | Step-down | Stress Test | Total |
|--|--------|---------|----------|-----------|-------------|-------------|
| LOS (days) | Varies | 3.0 | 0.2 | 2.0 | N/A | 5.2 |
| Continuous ECG Monitoring Event Frequencies | | | | | | |
| Admission (depart on transport) | - | 1.0 | 1.0 | 1.0* | 1.0* | 4.0 |
| Baths per LOS | - | 4.6 | 0.0 | N/A | N/A | 4.6 |
| Ancillary transports per LOS | - | 3.3 | 0.0 | 1.0 | N/A | 4.3 |
| False Alarms per LOS [†] | - | 31.9 | 2.6 | N/A | N/A | 34.5 |
| Depart (onto transport) | - | 1.0 | 1.0 | 1.0** | 1.0* | 4.0 |
| 12-lead/Stress Test Event Frequencies | | | | | | |
| 12-lead tests per LOS | - | 5.2 | 1.0 | 2.0 | 1.0 | 9.2 |
| 12-lead artifacts per LOS [‡] | - | 1.6 | 0.3 | N/A | 0.8 | 2.7 |
| Total # of Events | | | | | | 63.3 |

*Most events require both an attachment and detachment except those upon first entry to the ER (one attachment; detachment is from EMS) or departments with no hard-wired continuous monitoring (Stepdown unit and Stress Test lab).

**One detachment upon hospital discharge

†10.8 observed false alarms per patient per 24 hour for all departments

‡0.30 artifacts per 12-lead ECG in ER, ICU/CCU, Cath lab; 0.73 artifacts per 12-lead ECG in stress test lab

Source: The Lewin Group in-hospital data collection and interviews with 34 hospital staff personnel in Los Angeles, Philadelphia, and Washington, D.C.

Timing

Timing of all lead wire attachments/detachments were measured using stopwatches across various departments in four study hospitals and two EMS units. Stopwatch timing started when a nurse or technician began to handle lead wires to apply to/detach from the patient's body and ended when the last lead was placed on/detached from the patient's body. Variation in lead wire attachment and detachment timing is not due to department-specific characteristics. Rather, lead wire attachment and detachment timing varies with factors such as individual staff habit and experience; amount of clothing or gown/blankets to be removed during lead wire application/detachment; number of tubes and other monitoring wires on the patient's body; and patient type (i.e., elderly and/or female patients, for whom extra time and care was taken). Thus, the analysis used the mean time observed across all departments (Table B3).

Table B3. Mean Time of Lead Wire Attachments/Detachments (number of observations)

| Activity | ER | ICU | CCU | Cath Lab | PACU | Stress Test Lab | Step-down | EMS | Transport | Mean |
|---------------------------|-----------|----------|-----------|----------|-----------|-----------------|-----------|----------|-----------|------------|
| Continuous Monitor-Attach | 35.4 (16) | 59.9 (2) | 44.6 (5) | 67.0 (4) | 31.2 (15) | N/A | N/A | 51.1 (3) | 62.5 (2) | 41.7 (47) |
| Continuous Monitor-Detach | 20.0 (1) | N/A | 38.0 (3) | 18.8 (1) | 22.6 (4) | N/A | N/A | 13.3 (5) | 10.3 (2) | 20.3 (16) |
| 12-Lead Monitor-Attach | 63.7 (31) | 81.4 (6) | 63.1 (13) | 78.6 (3) | 54.1 (4) | 76.6 (22) | 58.7 (42) | 56.5 (2) | N/A | 64.9 (123) |
| 12-Lead Monitor-Detach | 12.7 (30) | 16.9 (6) | 29.4 (12) | 40.0 (2) | 16.5 (4) | 14.0 (20) | 29.1 (42) | 19.5 (2) | N/A | 21.5 (118) |

Source: The Lewin Group in-hospital data collection

Although 4-lead wire transport monitors were observed to be used in hospital study sites, the study was unable to capture a significant number of timings for transport attachment/detachment. As a result, mean time measurements for 4-lead wire transport monitor attachment (33.4 seconds) and detachment (16.2 seconds) were derived from the mean 5-lead wire continuous bedside attachment and detachment timing (41.7 seconds and 20.3 seconds) by adjusting for the number of lead wires.

Responding to False Alarms and Correcting Artifacts

Frequency

The frequency of false alarms with continuous ECG monitoring during a patient's stay was obtained from both direct observation and supplementary interviews.

In-hospital observation yielded 10.8 false alarms per patient per 24 hours based on the frequency of false alarms across patient-occupied beds in the ICU/CCU.

However, during supplementary interviews, ICU/CCU nurses reported a much higher frequency of 41.6 false alarms per patient per 24 hours. This large difference between observed and reported frequency suggests that the self-reported frequency of false alarms may be overestimated due to nurses' perception of the burden associated with correcting false alarms. Furthermore, the study observed that staff often wait for alarms to self-correct (i.e., wait for patient to calm and alarm to cease) before attending to a patient. Nevertheless frequent false alarms may result in potential delays in nurse response or attendance to patients or ignoring the alarms completely. Desensitization of nurses to alarms carries the risk that intervention may be too late.

The baseline model described in this paper includes the lower observed frequency of false alarms as a baseline estimate; the higher nurse estimate is included in a sensitivity analysis.

The frequency of 12-lead ECG artifacts was obtained from nurses and technicians. Artifacts were reported to occur with 30 percent of all 12-lead ECG tests in ER, ICU/CCU, and Cath lab, and with 73 percent of all stress tests.

Timing

Staff time associated with correcting false alarms and artifacts was obtained from supplementary interviews. The reported mean times spent to correct false alarms and artifacts were: 5 minutes for continuous ECG monitor false alarm across all departments, 8 minutes for correcting a 12-lead test in the ER, ICU/CCU, and Cath lab, and 10.3 minutes for correcting a stress test artifact. The mean time includes the time to leave the station and attend to the patient, correct the false alarm, and then return to the original location.

Cleaning of Lead Wires and Trunk Cables

Frequency

Nurses and ECG technicians provided the frequency of cleaning for both continuous and 12-lead ECG monitor lead wires and trunk cables during a patient stay.

- Continuous bedside monitor lead wires and trunk cables are cleaned once per patient stay in each department
- 12-lead monitor/stress test lead wire and trunk cables are cleaned every two days in the ER, ICU/CCU and Cath Lab, and once every test in the Stress test lab

Timing

Respondents also estimated the amount of time spent during each cleaning.

- In the ER, 1 minute is spent for each continuous ECG monitor lead wire and trunk cable cleaning; 2.8 minutes are spent for each 12-lead ECG monitor lead wire and trunk cable cleaning
- In the ICU/CCU, 2 minutes are spent for each continuous ECG monitor lead wire and trunk cable cleaning; 5.5 minutes are spent for each 12-lead ECG monitor lead wire and trunk cable cleaning

- In the Cath lab, 4 minutes are spent for each continuous ECG monitor lead wire and trunk cable cleaning; 7.5 minutes are spent for each 12-lead ECG monitor lead wire and trunk cable cleaning
- In the Stress test lab, 10 minutes are spent for each 12-lead ECG monitor lead wire and trunk cable cleaning

Since lead wires do not contact the patient's body with WECG, the study assumed that the time involved in cleaning the lead wires and trunk cable is eliminated with WECG. Any staff time that may be necessary for cleaning WECG's Patient Transceiver was not included in this analysis.

Nurse Wages

Nurse wage estimates (\$22.01 hourly without adjusting for benefits; \$31.00 with benefits) were taken from the U.S. Department of Labor, Bureau of Labor Statistics, 2002.

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