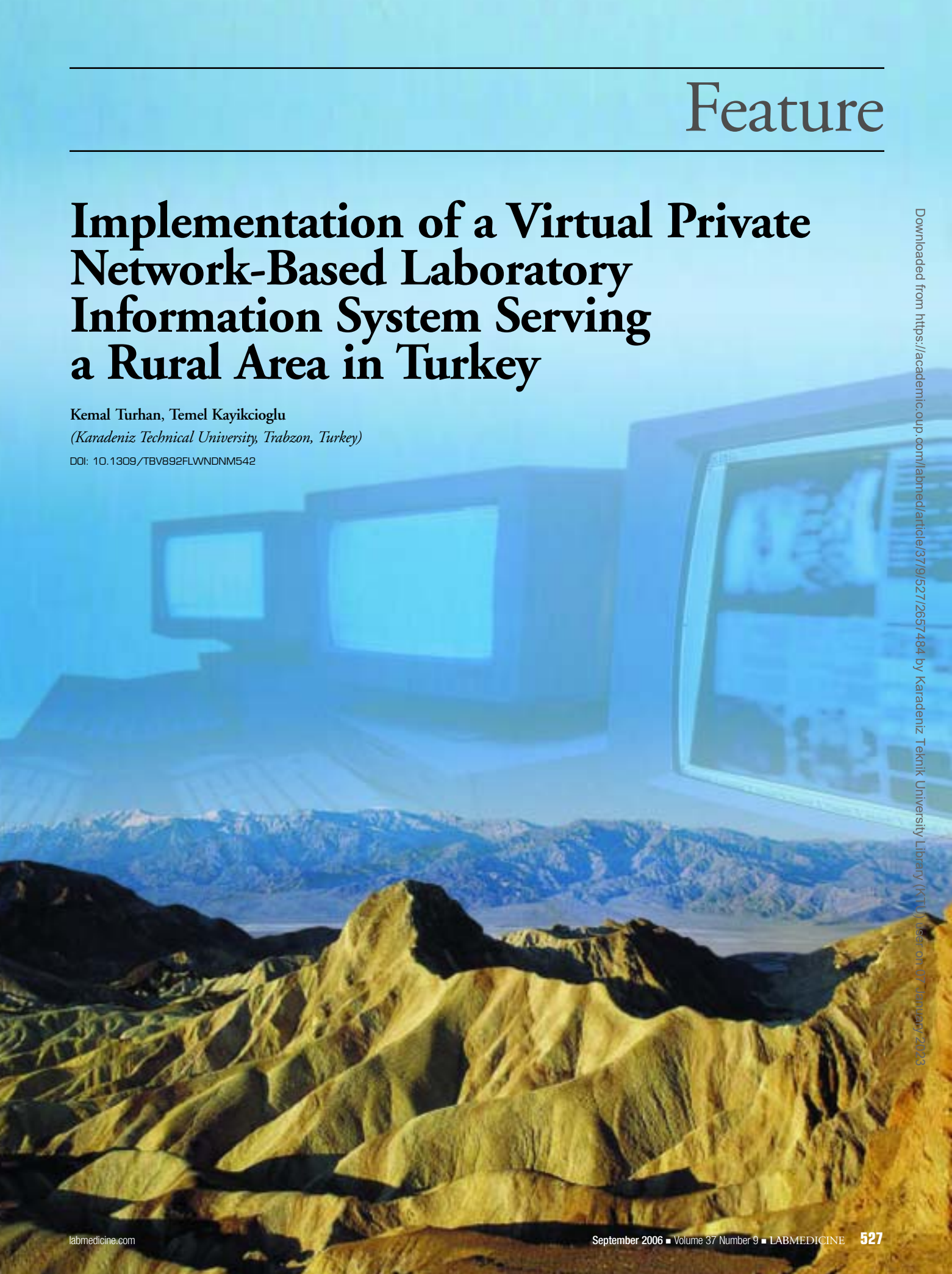
Implementation of a Virtual Private Network-Based Laboratory Information System Serving a Rural Area in Turkey

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In many developing countries, including Turkey, many factors hinder access to quality and affordable health care for people who live in rural areas.[1] These factors include severe geographic and weather conditions, a shortage of doctors and other health care professionals, distance between patients and health facilities, and long turnaround times (TAT) for completing and reporting laboratory results. Consequently, patients who live in rural areas mostly prefer to visit the primary hospitals, even if they live far from them and they have to pay for a tiring and expensive trip. Furthermore, this increases the work load of the primary hospitals. For countries with limited medical expertise and resources, a meaningful and economical integration of communications, information, and medical technologies will reduce the problems no matter where the patient lives. Telemedicine offers the potential to address these concerns and to save the patient extra costs that are associated with treatment, such as travel and other living expenses.[1] There are many telemedicine applications, such as teleradiology, telecardiology, telepathology, mental health, electronic medical records, and laboratory information systems (LIS).

Clinical laboratories play a crucial role (70%) in clinical decisions (admittance, discharge, diagnosis, and therapy), and measures taken to counteract economic problems are directed towards consolidating laboratories, and developing a network among hospitals, territories, and centralized laboratories.[2] As a limited number of advanced laboratories are available at central hospitals or central laboratories in big cities, designing a Virtual Private Network (VPN)-based LIS becomes urgent. In such telemedicine applications, blood specimens from patients are sent to those laboratories for analysis. The results are stored in a single database and become electronically available for all health institutions within the network. Based on the stored data, many applications (such as decision support models, care management, automated remainders, and alerts for selection of dosing of medication) can be developed.

In this study, we describe a VPN-based LIS to serve remote-entry test orders and to access the results of clinical analyzers, with the aim of significantly reducing TATs for laboratory services in rural areas. The system was implemented for clinical laboratory services [such as managing ELISAs, complete blood counts (CBCs), and biochemistry tests] that were ordered from 13 different primary health care units in Gumushane's rural areas in Turkey. With this implementation, 2 laboratories in this region—Gumushane Center Laboratory (GCL) and Kelkit Center Laboratory (KCL)—were converted to rapid response laboratories. Currently, the results of blood specimens are reported to primary health care units that have significantly reduced TATs.

Province's Situation

The Gumushane province is situated in the East Black Sea region of Turkey; its total land area is 10,230 km^2. According to the 2000 census, the population is about 187,000, and the population density is less than 18 per km^2. The province consists of a city (Gumushane) and 5 towns (Torul, Kelkit, Kurtun, Siran, and Kose). The population density is irregular throughout the province, as 41.5% of the population lives in the capital city and the towns, whereas the remaining population lives in the rural area where the population density is less than 11 per km^2.

The province has 5 state hospitals with a capacity of 355 beds, 2 central laboratories (GCL and KCL), and 29 primary health units. Of the 829 medical staff, only 29 are specialist doctors and 102 are practician doctors—an average of 1 physician per 1,416 inhabitants. Furthermore, the distribution of medical doctors throughout the province is more centralized than the population and the general medical population. The central laboratories are owned and operated by the city's health board. The blood samples collected from the primary health units are analyzed at these laboratories. The health services in Turkey are built up as a hierarchical structure that cooperates between a series of health care institutions locally, regionally, and nationally. Based on the results of various tests collected during diagnosis of a disease, patients are dispatched from local health institutions to higher ones.

The Turkish Telecom is the sole provider of line-based telecommunications network. It provides all such needs of the community. A digital communication network is available in the capital city and towns. All health care locations have access to the Internet through this network. Access is improved by using asymmetric digital subscriber line (ADSL)-based connections. An ADSL modem depends on advanced digital signal processing and creative algorithms, and enables faster data transmission over copper telephone lines compared with conventional modems. The speed or capacity of a modem is measured in the number of bits it can transfer per second. For conventional ADSL, speeds start at 256 kilo bits per second (kbps) and typically reach 8 mega bits per second (Mbps).

Regarding its surface topography, the province is a typical mountainous region with an elevation of 1,200 to 3,330 meters. Almost 60% of the province is occupied by mountains, whereas plateaus cover only 11% of the region. Distances from Gumushane to Torul, Kose, Kurtun, Kelkit, and Siran are 24, 50, 60, 75, and 103 km, respectively. The capital city, Gumushane, is not situated in the central part of the province land.

The winters are harsh, with an average temperature of around –2°C; most days it can drop down to –10°C. From the beginning of December to the end of April, 1–1.5 meters of snow covers the whole province. The average yearly rainfall is 410 mm. As most parts of the province are mountainous, winter driving conditions in the province naturally tend to be more difficult. Some roads that run over mountain passes are closed throughout the winter, although all the main roads in the towns and the city remain open except when they are blocked by snowfall during periods of extreme weather conditions. The geographical isolation, transportation challenges, harsh winter climate, availability of telecommunications infrastructure, and the innovativeness of regional health care leaders have provided the ideal setting for the deployment of VPN-based LIS in Gumushane's rural area.

Technological Barriers to a VPN-Based LIS System

Addressing the potential technological barriers for a telemedicine application is necessary, as reported by some researchers.[3-6] A VPN-based LIS links laboratories at geographically dispersed locations and provides clinical information to participating sites. It consists of clinical analyzers for blood tests, a database for keeping and managing patient clinical information, online document sending and receiving units, personal computers used to send patient information and receive clinical information, software and a telecommunications network. Integration of these components poses some technological barriers,

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including the communication interface of clinical analyzers, security, and affordable telecommunication technology. To gain an acceptable VPN-based LIS, the effects of these barriers should be minimized in the implementation.

There are currently many types of clinical analyzers that are manufactured by different companies. Most of them have microprocessors that manage acquisition, storage, analysis, and communication signals and measurements. The wide variety of popular clinical analyzers have many operational, functional, and other differences. Furthermore, they lack a standard communication interface. Consequently, the transfer of information among the components of a VPN-based LIS is difficult and requires software development.[7-12]

The laboratory information system uses a database for keeping and managing patient information. Therefore, such systems require a high degree of security for keeping information away from unauthorized access. One solution for security is to lease a private network. Such networks, called VPN, are closed to the outside world as there is no gateway into them.

The cost of telecommunications is a major issue in implementing a telemedicine application and is determined by the type of technology. The type of telecommunications technology to be used in a telemedicine application depends on the amount of information that may be sent per unit of time. Currently, there are many types of technologies. Although advanced technologies are capable of carrying more information at faster speeds, telecom providers do not consider them in telemedicine applications due to mountainous terrain and long distances. Consequently, the telecommunication technology to be used by a telemedicine application is determined by the available local infrastructure that is usually a line-based telephone system. As relatively small quantities of text are needed to be transferred, ADSL-supported telephone systems can be used in the implementation of a VPN-based LIS.

Description of the Implemented System

GCL has 3 clinical analyzers (Cobas Integra 800, Vitros EciQ, and Coulteract DIFF), whereas KCL has only 2 clinical analyzers (Konelab 60i and Coulteract DIFF). GCL is implemented as the center laboratory and involves a database (Oracle 8.1.7) system. The primary health units in Gumushane, Torul, Kurtun, Oz Kurtun, Tekke, Arzular, Kose, and Siran are connected to GCL via a 512-kbps capacity of ADSL modem, whereas the KCL is connected to GCL via a 2048-kbps capacity of ADSL modem, as this center has 2 analyzers that are capable of accessing the GCL database for test queries of bar-coded samples. The implemented system works on a real time basis based on the transmission control protocol/Internet protocol (TCP/IP), no matter where the analyzers and the database are located.

To develop host communication interface software for collecting and disseminating data captured from clinical analyzers (Vitros ECiQ, Cobas Integra 800, Coulteract DIFF, and Konelab 60i), Borland Delphi and the TMS Async32 component programming tools for RS232 communication were used.[13,14] The RS232 is a standard for asynchronous serial data communications between personal computers and external devices.

The software being developed is user-friendly and communicates not only with the HIS and LIS, but also with laboratory analyzers that are located in Gumushane and Kelkit via secure VPN. The HIS software, based on Oracle Forms and Reports, was developed to meet requests such as test orders from physicians, test results, and billing. HIS software is commercially available and manages information flow in different locations on the VPN.

Workflow of the Former System

The former system worked as follows. When a patient being seen by a physician in a health care unit required a laboratory test, the test order was checked on the laboratory form. This form had the following information: name of primary health care unit, name of patient, personal health care number, specimen type and tests requested, and name and telephone number of contact person. A label having the correct information, including name of patient, personnel health care number, and name of health care unit was attached to the blood sample tube. As seen from **Figure 1**, all blood sample tubes, as well as laboratory forms collected by the transportation staff, were transported to the closest laboratory center (GCL or KCL) by a vehicle. The staff submitted the tubes to the laboratory in the mornings (Monday to Friday), then returned to their work

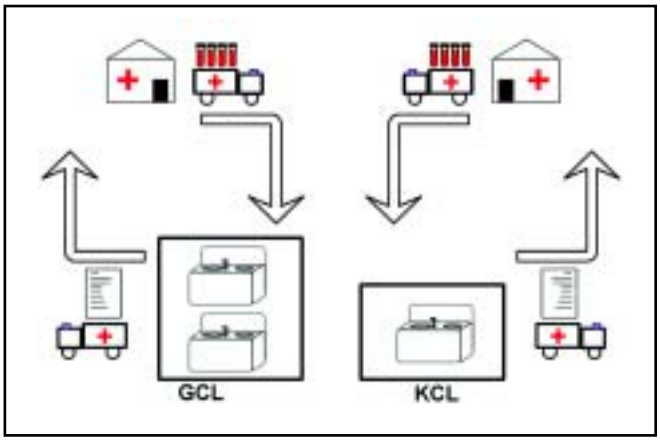


Figure 1_Transporting blood samples and test results using the former system.

places. The information on the laboratory forms were manually entered into the analyzers by the laboratory technician. The technician also read the label on each tube, ensuring that the correct specimen was being collected from the right patient. The test results becoming available were collected from the laboratory and transported to the primary health care units again by vehicles in the afternoons. In the case of urgent requests, test results were sent via telephone or fax.

Workflow of the Implemented System

The implemented system proceeds as follows: when a patient being seen by a physician in a health care unit requires a laboratory test, the test orders, as well as the patient information, are entered in real-time into the database that is located at the GCL through a personal computer that is connected to the VPN. The barcode label that is produced by the system for the patient and the specimen is printed and attached to the blood sample tube. The label also includes text information indicating the name of the analyzers. As seen in **Figure 2**, only bar-coded blood sample tubes are collected and transported to the closest

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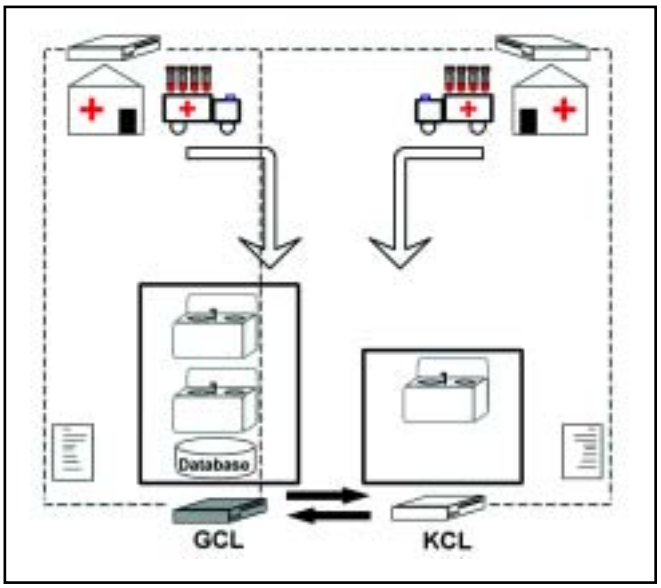


Figure 2_Transporting bar-coded blood samples and test results using the implemented system.

laboratory center by a vehicle. The laboratory technician does not do any work, except for putting the tubes in the analyzer racks. After the clinical analyzers read barcodes on the tubes, they perform test order queries from the GCL database according to the host communications protocol. The test results that are produced by the clinical analyzers are automatically sent to the GCL database. The results that are approved by the laboratory technicians become remotely accessible by authorized medical staff at all health locations within the system.

Results

One of the most important quality indicators of the clinical laboratory is the TAT of the test orders. Corrective measures taken in the pre-analytical (changes in organization) and in the post-analytical (changes and integration of telematics) phases have resulted in a 30% reduction in TAT.[15] Therefore, to decrease TAT and to potentially add value to laboratory results, laboratories have reorganized and re-engineered so that they operate in a highly automated manner.[16,17] Therefore, the main objectives of this study are: to reduce TAT, improve the test order entry process and to gain automatic access to test results, set a sample identification system by bar-coding and labeling the samples, reduce the operational and administrative costs, and promote the quality of laboratory services for the Gumushane's rural area.

As a result of the implementation of a VPN-based laboratory information system, a number of health care services are offered instead of the former system:

1. Laboratory test results TAT is the time between collection of specimens and availability of laboratory test results. A nurse no longer needs to write patient information and test orders on a laboratory form and prepare a label for a tube. Bar-coded tubes are immediately loaded to the clinical analyzers. Test results become electronically available. Therefore, TAT is mainly determined by transportation and analysis of specimens. After implementation, TAT for routine samples is decreased from 1 day to half a day.

2. In the past, routine results were usually available 1 day after receipt. Therefore, physicians were unwilling to order more tests. As the laboratory services were at a low level due to a long TAT, most inhabitants of the rural area preferred to directly visit the state hospital laboratory center instead of the closest primary health care unit. Two laboratories processed an average of 100 blood samples per day; today, this figure has increased by an average of 100 per day. This implies that, within a matter of 2 months, nearly 4,000 patients have obtained test results without traveling to the state hospital laboratory center.

3. With the implemented system, all health care staff in the primary health care units are able to gain quick and easy access to the latest laboratory results and are able to review a patient's historical record. The quality of patient information that is available to physicians and nurses is much better than it was when they relied solely on a paper chart. All documentation is electronic. It has also decreased errors occurring anywhere in the process flow.

4. It has not only reduced the costs of health care units but has also automated the financial and administrative functions. Managerial oversight and administrative workflow patterns have improved. All primary health care units are able to conduct cost/benefit analyses.

5. As the routine results are immediately delivered to primary health care units in half a day, the physicians do not transfer their patients to a state hospital if the patient's health case is curable by medication. Therefore, the medical service for patients who are isolated due to weather and transport conditions has been reduced.

6. This system has improved referral linkages of the health care units within the system.

7. This system has improved the productivity of medical staff in GCL, KCL, and primary health care units. Health care staff in the primary health care units have found a reduction from 7 minutes to 1 minute for the process of entering test orders into the system. The implemented system has enabled the laboratory technicians to place the bar-coded tubes directly into the analyzers' racks, thereby eliminating time-consuming, pre-analytical steps. These steps, which previously took about 30 minutes to complete, now take only about 3 minutes.

8. On each day, 4 vehicles traveled a total of about 800 km to transport blood samples and to disseminate test results. After implementation, this figure has declined by a half. The cost of a vehicle trip per km is 0.125 euro. This implies that the daily cost saving from transportation is 50 euro. Multiplying this figure by the number of weekdays in a year (about 260 days) yields an annual cost saving of 13,000 euro. In addition, the total time spent by 4 vehicle staff decreased from 32 to 16 hours per day. Therefore, it has reduced the operational costs of transporting patient samples and disseminating test results.

9. In the past, the revenue of the health board was about 55,000 euro per month. The implemented system has allowed more tests than before implementation to be processed. Therefore, although the number of blood samples processed increased by 2 times, the annual laboratory revenue went up 4 times, from 55,000 to 220,000 euro per month.

Conclusions

In this study, we described a VPN-based information system that was implemented for providing remote-entry test orders and for accessing results of clinical analyzers, with the aim of reducing TATs for laboratory services for the inhabitants of the rural area of Gumushane province, situated in the East Black Sea region of Turkey. About 50% reduction in TATs has been achieved by using information and telecommunication technologies.

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Due to budget limitations, this network covers only 13 health care units. The implemented system has been well received by the patients and medical staff, and the benefits that have been gained using this system have made the province health care policymakers realize the need for adding the remaining health care units to the system in the near future.

Rural areas in developing countries face various problems in the provision of medical services and health care, including funds, expertise, resources, all of which relate to the lack of facilities and systems. The rural area in which the system discussed here was implemented has similar problems. As costs decrease for many information and communications technologies that support telemedicine applications, health care organizations in these areas seek to develop cost-effective telemedicine applications. The system was implemented using such cost-effective technologies. LM

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