Development of an educational research software with advisory role in the interpretation of calcium and phosphorus laboratory tests in human serum and/or urine

Delimaris I.[1], Delimaris K[2]

1. External Postdoctoral Research Team Member at the MBioRF project, Greece
2. School of Pedagogical & Technological Education (ASPETE), Greece

Corresponding author: Dr. Ioannis Delimaris, e-mail: dr.i.delimaris@gmail.com

Abstract

Background: Clarifying the exact etiology of pathological levels for calcium and/or phosphorus in human blood and/or urine is not always an easy task. Hyper/hypo-calcemia/calciuria and hyper/hypo-phosphatemia/phosphaturia sometimes could complicate a differential diagnostic procedure.

Objectives: The purpose of the present study was to develop a free, simple stand alone educational research software (ERS) to aid the education of clinicians and healthcare laboratorians (or undergraduate students) in interpreting calcium and phosphorus laboratory tests in human serum and/or urine (for adult patients).

Materials and methods: The software was designed using: a) Microsoft Windows as operating system, b) the Adobe Flex software development kit (SDK), and c) MXML as programming language. The (ERS) is compatible with Linux. It can be distributed on Compaq Disk (CD) and be run on any Personal Computer (PC) on Windows.

Results and discussion: The developed (ERS) -which we have called DCPS v.1.0- does not require wide knowledge and expertise in computers. Its educational benefits include interactive format, self-paced learning, feedback, understanding of the basic clinicobiochemical processes that underlie several pathological states, and usability outside timetabled course.

Conclusions: The free (ERS) could be a useful teaching tool in clinical laboratory education. Future work should focus on further evaluation of its accuracy, its usefulness on the teaching process and its acceptance by the healthcare students or professionals.

Keywords: clinical biochemistry, digital learning, biomedical informatics.

I. Introduction

The homeostasis of calcium (Ca) and phosphorus (P) in humans is a complex biological phenomenon. The adult human body contains about 1200 g of calcium, which amounts to about 1–2% of body weight. Of this, 99% is found in mineralized tissues, such as bones and teeth, where it is present as calcium phosphate (together with a small component of calcium carbonate), providing rigidity and structure. The remaining 1% is found in blood, extracellular fluid (ECF), muscle, and other tissues (Gibney et al., 2009). Most phosphorus within the body is in bone (600– 700 g); the remainder is largely distributed in soft tissue (100–200 g). As a consequence, less than 1% of the total is in extracellular fluids. The plasma contains about 12 mg/dL of phosphorus, of which approximately 8 mg is organic and contained in phospholipids, a trace is an anion of pyro-phosphoric acid, and the remainder is inorganic phosphate

(Pi) (Yanagawa et al., 1994). Although measures of bone mass may be used as indicators of body calcium status (BMC: bone mineral content; the amount of mineral at a particular skeletal site, and BMD: bone mineral density; BMC divided by the area of the scanned region), clinical biochemistry tests are used to determine the concentration of calcium in the blood or urine (Lloyd et al., 1993). Roughly half of the calcium in the blood is "free" and is biologically active. The remaining half is "bound" to albumin and other compounds and is metabolically inactive. There are two laboratory tests to determine blood calcium levels: a) the total calcium test determines both the free and bound forms, b) the ionized calcium test determines only the free, biologically active form. Some calcium is lost from the body every day, filtered from the blood by the kidneys and excreted into the urine. Determination of calcium levels in the urine is used to estimate how much calcium is being eliminated by the kidneys (AACC, 2014). Regarding phosphorus, because its intake directly affects serum inorganic phosphate, the US Food and Nutrition Board considered that the most logical indicator of nutritional adequacy of phosphorus intake in adults is inorganic phosphate. If serum inorganic phosphate is above the lower limits of normal for age, the phosphorus intake may be considered adequate to meet cellular and bone formation needs of healthy individuals (Gibney et al., 2009). Phosphorus tests are most often ordered along with other tests, such as those for calcium, parathyroid hormone (PTH), and/or vitamin D, to help diagnose and/or monitor treatment of various conditions that cause calcium and phosphorus imbalances. While phosphorus tests are most commonly performed on blood samples, phosphorus is sometimes measured in urine samples to monitor its elimination by the kidneys (AACC, 2014).

Due to the complex nature of calcium and phosphorus homeostasis, clarifying the exact cause of its dysregulation (as reflected by abnormal values of calcium and/or phosphorus in the blood and/or urine) is not always an easy task. Hyper/hypo-calcemia/calciuria and hyper/hypo-phosphatemia/ phosphaturia may complicate the differential diagnosis of a disease. One of the tools that medical and laboratory personnel usually rely on to interpret laboratory results is the use of clinical biochemistry softwares. Yet, far too little attention has been paid to the development of a software for the interpretation of calcium and phosphorus laboratory tests with user-friendly characteristics as tools for educational research purposes. The aim of this study was to develop a free, simple stand alone educational research software (ERS) to assist clinicians and laboratorians (or undergraduate students) in interpreting calcium and phosphorus laboratory tests in human serum and/or urine (for adult patients).

II. Materials and methods

System Design

The design of the system was initially done on paper withall the relevant stages and data processing outlined clearly. The mathematical algorithms were detailed in simple English language for easy of programming.

Implementation

The minimum hardware requirements for the (ERS) is a Pentium 4 processor (Intel) or equivalent and 1 GB of random-access memory. The required operating system is Windows XP Service Pack SP 2 or later (Microsoft), and the required software

component (plug-in) is Adobe Flash Player. Other computer requirements are: color graphics screen; hard disk drive; mouse; and CD ROM drive.

Development

Data for hyper/hypo-calcaemia/calciuria and hyper/hypo-phosphatemia/ phosphaturia were collected and evaluated from internet biomedical databases and clinical biochemistry textbooks (Ζουλλιέν, 1993; Moe et al., 2008; Marshall et al., 2008; Gaw, 2008). Control commands were added in an MXML file. The developed software can be distributed from one Personal Computer (PC) to another using a flash drive, a compact disk, or any portable medium. The (ERS) is compatible with Linux.

III. Results and discussion

The development of the software-which we have called DCPS (Delimaris Calcium-Phosphorus Software) v.1.0- doesn't demand special skills and expertise in computers. When the user logs into the system, a default page becomes visible with data in Greek language. Initially, the user enters the reference range values (RRV) into the system for: a) serum " ionized "calcium, b) serum phosphorus, c) serum alkaline phosphatase, d) urine calcium, and then clicks the "load" button; immediately after entering the values for each tested parameter the software defines which values are considered as "low" and "high", respectively (Figure 1).

Figure 1 : An illustration of the screen from the ERS that appears after entering the reference range values.

(RRV) for human serum/urine tests are used by a health professional (physician, clinical biochemist, dietician, medical technologist, etc.) to interpret a set of clinical test results. The (RRV) may vary between different laboratories due to different equipment and different methods or standardization of the analysis. Therefore, each laboratory should establish its own (RRV) and the patient (or the physician) must take into account the (RRV) of the laboratory where the specific analysis was done and not a theoretical or " ideal " (RRV), which has been published in a textbook. The term (RRV) is preferred over the term " normal values " because the reference population can be defined precisely. So, instead suggesting that the test result will be compared with a not well defined "normal" pattern, the (RRV) indicate that the results are compared with a well- defined and known population (AACC, 2014).

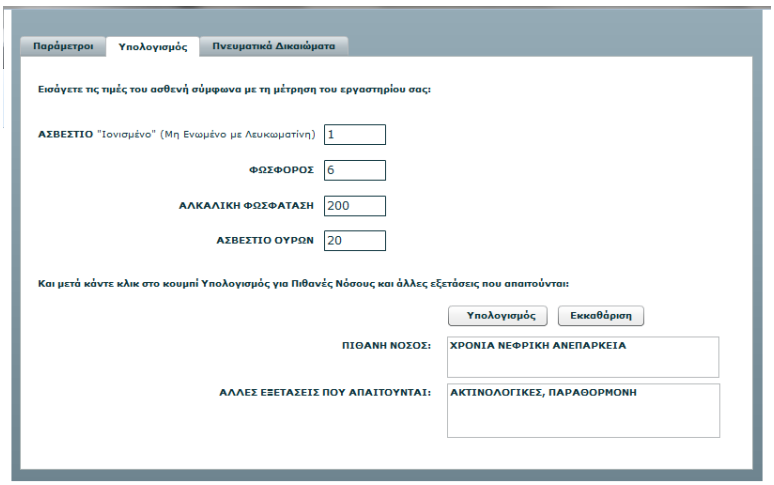

Figure 2a : An illustration of the screen from the ERS that appears when the laboratory data/results have been entered. It provides a potential diagnosis (renal disease) and other additional laboratory tests that might required (X-rays, parathyroid hormone).

After loading the (RRV) into the system the user enters the individual patient's serum values. By clicking on the "calculation " button, the possible diagnosis and other tests that may be required are displayed on the computer monitor (Figure 2).

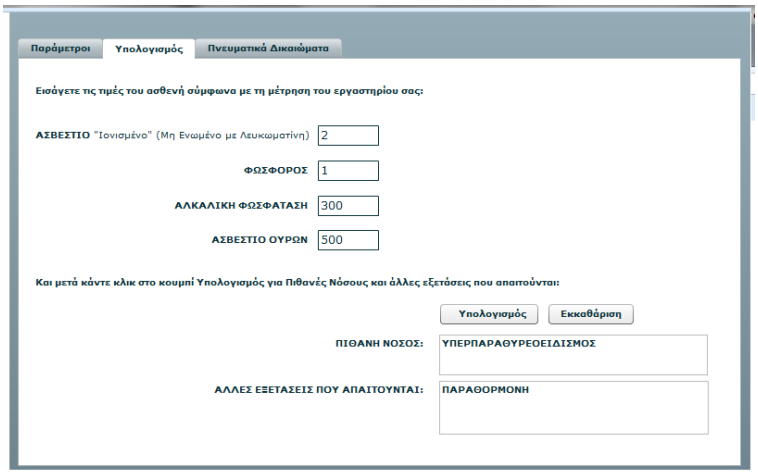

Figure 2b : An illustration of the screen from the ERS that appears when the laboratory data/results have been entered. It provides a potential diagnosis (hyperparathyroidism) and other additional laboratory tests that might required (parathyroid hormone).

It is widely accepted that computer learning programs are effective learning tools and are a useful addition to traditional teaching methods in biomedicine (Andrews et al., 1992). It has been shown that they could expand students' knowledge base, as well as improve data-handling abilities and clinical problem-solving skills (Devitt et al., 1998). In particular, the developed (open access, free) interactive software could be used by undergraduate students to bridge the gap between the theoretical underpinnings of biochemistry with clinical medicine via the provided simulated clinical cases. The exploratory and discovery learning through analyzing the possible diseases and the additional tests that may be required is an important strategy for

biomedical education, because the student is encouraged to observe, assume, test cases and produce scientifically accepted conclusions (Delimaris, 2014).

IV. Conclusions

In conclusion, the developed (free) DCPS v.1.0 has been designed to be a supplemental learning environment for healthcare students and it could be helpful as an educational research tool. The educational benefits of the developed (ERS) include interactive format, self-paced learning, feedback, understanding of the basic clinicobiochemical processes that underlie clinical problem-solving, and usability outside timetabled course. Further work is needed so as to find possible ways to improve its ability for accurate and precise diagnosis and to evaluate its usefulness on educational purposes by healthcare laboratory scientists specialized in clinical biochemistry (biologists, biochemists, chemists, medical technologists etc.) or physicians.

References

1. American Association for Clinical Chemistry (AACC), Labtests on line (2014): http://labtestsonline.org
2. Andrews PV, Schwarz J, Helme RD. Students can learn medicine with computers. Evaluation of an interactive computer learning package in geriatric medicine. Med J Aust. 1992;157(10):693-5.
3. Delimaris K, Delimaris I. Development of an educational research software for detection of clinically important drug-drug interactions E-Journal of Science and Technology (e-JST). 2014;9(1): 1-5.
4. Devitt P, Palmer E. Computers in medical education 1: evaluation of a problem-orientated learning package. Aust N Z J Surg. 1998;68(4):284-7.
5. Gaw, A. (2008). Clinical biochemistry: an illustrated colour text. Elsevier Health Sciences.
6. Gibney, M. J., Lanham-New, S. A., Cassidy, A., & Vorster, H. H. (Eds.). (2009). Introduction to human nutrition. John Wiley & Sons.
7. Lloyd T, Andon MB, Rollings N, et al. Calcium Supplementation and Bone Mineral Density in Adolescent Girls. JAMA. 1993;270 (7):841-844.
8. Marshall, W. J., & Bangert, S. K. Clinical biochemistry: metabolic and clinical aspects. Churchill Livingstone, 2008, Gaw, A. (2008). Clinical biochemistry: an illustrated colour text. Elsevier Health Sciences.
9. Moe, Sharon M. Disorders involving calcium, phosphorus, and magnesium. Primary Care: Clinics in Office Practice, 2008;35 (2): 215-237.
10. Yanagawa ,N., Nakhoul, F., Kurokawa, K., and Lee , D.B.N. (1994). Physiology of phosphorus metabolism. In " Clinical Disorders of Fluid and Electrolyte Metabolism " (R.G. Narins, ed.), 5th ed McGraw-Hill, New York.
11. Ζουλλιέν (1993) Διαταραχές ισοζυγίου νερού και ηλεκτρολυτών, σελ. 73-84, "Οξεοβασική ισορροπία", Περιλήψεις Σεμιναρίου της Ελληνικής Εταιρείας Κλινικής Χημείας-Κλινικής Βιοχημείας.