An implementation guide for a CDA report about cardiopulmonary exercise testing (CPET) results in the Austrian health record

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Abstract

In this article we present an answer to the question how difficult might it be, to define a working CDA report that fulfills the requirements of the Austrian specifications of the nationwide electronic health record called ELGA. We chose the results of standardized cardiopulmonary exercise testing (CPET) results as an example document. We therefore analyzed existing documentation and interviewed sport scientists and medical doctors to find out how this type of medical documentation is best structured and what data must be and can optionally be included. We then worked out the appropriate elements of a CDA report for levels 2 and 3. Only one adaptation had to be made to the official Austrian health records stylesheet, which was necessary to be able to integrate scalable vector graphic (SVG) images. After this project we can conclude, that the time and technical effort to construct documents for the nationwide Austrian electronic health record is quite little. The biggest problem still might be to obtain a consensus of all involved parties when trying to define an official report, which was not necessary in our case

Keywords

Electronic Health Record, CDA level 2, CDA level 3, CDA report, implementation guide

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1 Introduction

Beginning with mid 2013 the Austrian minister of health will introduce a nation wide electronic health record (in German called "Elektronische Gesundheitsakte" or short ELGA). This is one of the cornerstones of the Austrian eHealth strategy [1]. It will start with only a few core applications like medication, and will be expanded during the following years with more aspects like laboratory results, radiology records, vaccination record, etc.

The ELGA will be based on international standards like HL7/CDA, LOINC and IHE profiles like XDS. Docu-

ments in these health records will be formatted according to CDA release 2. All documents in the ELGA must have a maximum level of compatibility. Therefore the agency in Austria to coordinate and facilitate the implementation – former ARGE ELGA, meanwhile called ELGA GmbH [3] – releases central implementation guidelines and stylesheets. This is valid for at least the header section of the documents. The bodies of the employed documents, the medical contents themselves, must be consistent with nationally harmonized implementation guidelines, which are to be derived from international guidelines.

This model enables interested parties, to develop nationwide harmonized report and document definitions for each and every necessary or interesting medical case. The current ELGA model in Austria can also be seen and used as a toolbox, where you can get reference standards, implementation guides, etc., pick the appropriate header parts, define body elements according to the data to be stored and develop stylesheets to display the data correctly.

In this project we also enforced this strategy. We set our goal to find out, how easy or tricky it would be to generate a new sort of document that would be suitable to be integrated into the Austrian nationwide health record. We looked to choose a domain where there was no active development or already published standard available to date.

1.1 Cardiopulmonary Exercise Testing (CPET)

One domain that might be of interest – but is definitely not a typical core application of health records – are cardiopulmonary exercise tests, that give answers to questions about how capable a patient is to perform sportive activity that might require endurance.

During medical or sport scientific performance analysis tests on healthy subjects, athletes or patients, several physiological parameters are collected with different measurement instruments to be able to judge the performance and/or training state of the specific subject. Relevant physiological performance parameters are amongst others e.g. the heart rate (HR), blood lactate concentration (LaC) and spirometric data like O_2 intake (VO_2), CO_2 output (VCO_2) and total ventilation (VE), to name only a few.

Based on these parameters algorithms should be able to calculate so called individual aerobic and anaerobic thresholds. Since these thresholds are the results of a highly dynamical system – the human body during exercise – there are several algorithms available that might also yield different results.

The results of the analysis of these parameters and thresholds are the foundation for a decision about therapies in case of health problems (like intensity and amount of movement therapy) or about training suggestions for an aimed increase of physical performance ability for athletes or more generally, active persons.

2 Methods

This document contains a draft specification of the contents of the diagnostic findings for a cardiopulmonary exercise test. The draft focuses on possibly becoming a part of the Austrian health record currently in development.

There a two official main foundations for this document. First, the central document "Implementation Guideline for CDA documents of the Austrian health care system" [2]. And second, we chose to use the "CDA laboratory report for the Austrian health care system – addendum to the implementation guideline" [4] for the structuring of the diagnostic findings according to CDA level 2 and 3.

2.1 Human readable vs. machine readable: CDA Level 2 or Level 3

CDA documents must be readable for human readers as a matter of principle. This is basically valid for all contents that have been signed and authorized by the creator. Technically, this has been implemented via the so called CDA text level ("Level 1") and section level ("Level 2").

Additionally, CDA documents can also contain coded parts that are meant for further automated machine processing, e.g. for the automatic generation of diagrams from data coming from findings that had been created at different points in time, like trends. These machine readable parts are technically placed in the so called CDA entry level ("Level 3") as a part of the documented findings.

The header on the one hand contains administrative data, like common information about the document, personal data of the patient, etc. and on the second hand is used partly also as a source for meta data, that are necessary for the registration of the document in the ELGA. The header of our document has already been designed to be compatible with the to date published documents of the ELGA. The relevant parts for the findings of the cardiopulmonary exercise tests are contained in the so called body of the document.

The specification at hand for these findings has been developed in cooperation with the sport scientific laboratory of the Graz University of Applied Sciences. Additionally medical doctors for sports medicine have been interviewed, to validate the documentation contents. The whole project was carried out at our department in collaboration with students. The project was basically divided into two phases: first, the determination of relevant data and second, the development of the guideline itself.

In the first phase, we interviewed several sport scientists and analyzed current documentation of cardiopulmonary exercise tests. Since not every sport scientific laboratory uses the same equipment, the data being collected is quite different, in terms of which data is being collected at all. Some are measuring only the heart rate, others additionally blood lactate, more rarely spirometric data is collected too. Starting with these raw values, the questioned individual aerobic and anaerobic thresholds can be calculated. All these data had to be coded according to the requirements of HL7. The results and details of this work will be reported in section 3.

In the second phase of the project, the coded elements were structured and combined in our implementation guideline. In the end, we had to adapt the more general XSL- and XSD-documents a little to be able to present our specific CDA-reports properly. For our cardiopulmonary exercise test reports the following documents are of primary interest as a foundation:

- CDA documents for the Austrian health care system – implementation guideline: basic guideline about the structure of CDA documents in Austria (in the following briefly called "CDA-guideline") [2]
- CDA laboratory report for the Austrian health care system – addendum to the implementation guideline: extends the CDA-guideline with those specifications that are necessary for the creation of a laboratory report as a CDA document ("laboratoryguideline") [4]
- ELGA reference stylesheet 1.01.009 RC: basic stylesheet for the human readable presentation of CDA documents in a browser ("CDA-style") [5]

3 Results

In this section we present and discuss the possible contents of a CDA document for cardiopulmonary exercise test results. For every single test result section we identified and documented the following information:

- definition of the data to be stored
- design of a possible later presentation in the browser
- possible coding of the data in the CDA document (example of structure) – for CDA level 2 and level 3 respectively
- possibly a necessary adaptation of the existing XSL document (for the human readable presentation in the browser)

To be able to report about our CDA implementation on only a few pages, a lot of information had to be omitted in this report. A more detailed version is available from the corresponding author. In the following subsections and paragraphs we will basically only describe the kind and amount of data that has to be stored to represent a complete cardiopulmonary exercise test result. We at least describe how we would suggest to code the data respectively, but have to omit every detail about the browser presentation or the actual coding in CDA level 2 or level 3.

3.1 CDA Header

Many elements in the header section of a valid CDA document are already predefined in the official Austrian CDA-guideline mentioned earlier in this report. All of these elements are also marked as required in the header and will not be further described. These elements are:

- the root element
- the realm of the document ("realmCode")

- document format (,,typeId")
- document-ID ("id")
- code for the confidentiality of this document ("confidentialityCode")
- code for language in which the document had been written ("languageCode")

The following paragraphs describe the header elements that we had to define ourselves. All of the elements following in this section are also part of the document header:

Template ("ClinicalDocument/templateId") The template defines the sum of limitations of this specification in relation to the CDA R2 standard. Because findings of cardiopulmonary exercise tests are currently not seen as a part of the ELGA, we are not able to give a specific definition of the "templateId". Probably, the "templateId" of CDA documents coming from cardiopulmonary exercise tests will also be included in the structure of ELGA core application Ids, like it is stated in the CDA-guideline, section 6.2.5.

Optionality: [R] [1..1]

Document class ("ClinicalDocument/code") The document class we use for our reports is the one of the "PERSONAL HEALTH MONITORING REPORT". **Optionality:** [**R**] [1..1]

Document title ("ClinicalDocument/title") The title of the document can be freely chosen by the document creator and describes the kind of document in more details. The meaning of the title has to be chosen according to the document classes. In most cases the title will be e.g. "Cardiopulmonary Exercise Test". **Optionality: [R] [1..1]**

Document date ("ClinicalDocument/effective-Time") The date of the creation of the document. The moment in time, when the document had been edited the last time.

Optionality: [R] [1..1]

Versioning of the document ("setId" und "version-Number") According to the specifications in the CDAguideline a versioning is required for all documents. Optionality: [RO]

Patient ("ClinicalDocument/recordTarget") To represent the patient, we adapt the specifications and structures from the laboratory-guideline (section 5.3.1 - patient). To be able to specify a possible sport club where a patient could be a member of, the element "patientRole" can be extended by an element "providerOrganization". This element is subject to the specifications of the CDA-guideline (5.11.1 – POCD_MT000040.Organization). **Optionality: [R] [1..1]**

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Creator of the document ("ClinicalDocument/author") Here again, we take the specification and structure from the CDA-guideline (6.3.2 - creator of the document). The author is the very person, who has authored the content of the document, not necessarily its writer (i.e. the author is the person who dictates a document, whereas the writer would be the person who types it). Optionality: [R] [1..*]

Custodian of the document ("ClinicalDocument/- 3.2.2 Personal data custodian") In each document it has also to be stated which organization is responsible for the custody and storage, including the archiving, etc. of the document. Also here, we take the specification and structure from the CDA-guideline (6.3.4 – custodian of the document). Optionality: [R] [1..1]

Legal Authenticator ("ClinicalDocument/legalAuthenticator") The legal authenticator is the person who takes over the legal responsibility of the contents of the document. This is also not necessarily the author. Again we borrow the specification and structure from the CDA-guideline (6.3.6 - legal authenticator). Optionality: [R] [1..1]

Service Events ("ClinicalDocument/documentationOf/serviceEvent") The element "documentationOf", represents the actual health care service, that is being represented in the document. This element is in a close relationship with the document type: with this element the health care service can be specified, but it must not lead to a contradiction with the document type. Here we borrow the specification and structure from the CDA-guideline (6.5.1 - service events). Optionality: [O] [0..*]

3.2 CDA Body

In the body we place all the elements that contain the real data from the cardiopulmonary exercise tests and its results, whereas the header mainly comprises meta data for the document itself. The contents of these elements now, are the results from our investigation of documentation coming from cardiopulmonary exercise testings for performance analysis. We discussed these findings with several sport scientific laboratories and medical staff, to gain a more common view on the necessities of the documentation.

3.2.1 General data of the examination

Opt	Element	Description
[R]	date	date of the examination
[R]	protocol	how has the examination taken
		place, which performance protocol
		had been used
[R]	parameter	which examinations had been
		done

Opt	Element	Description
[R]	height	physical height
[R]	weight	physical weight
[RO]	BMI	body mass index
[O]	bodyfat	the total bodyfat of the patient

The body mass index can be calculated from the physical height in centimeters and weight of a body in kilograms and is defined as

$$BMI = \frac{weight}{height^2} \tag{1}$$

The problem with the element bodyfat is that the value can vary extremely, depending on which measurement method had been used.

3.2.3 **Calculated Values**

Opt	Element	Description
[R]	heartrate	heartrate 3 minutes after stop
[R]	relative per-	fraction of heartrate after stop
	formance	to maximum heartrate
[R]	relative max-	relative maximum perfor-
	imum perfor-	mance in relation to the body
	mance	weight
[R]	blood lactate	resting blood lactate level
[RO]	maximum	maximum oxygen intake in
	oxygen	m liter/minute
	intake	
[RO]	maximum	relative maximum oxygen in-
	relative oxy-	${ m take~in~ml/kg/min}$
	gen intake	

In this section one can find rather self explanatory elements, that are either direct results of measurements, like the heartrate three minutes after stopping and the resting blood lactate level, or that had to be calculated or set in relation to other values, like the relative maximum oxygen intake, that depends on the bodyweight.

3.2.4 Thresholds and maximum values

Opt Element Description [R]maximum maximum performance, maxiperformance mum heartrate and maximum lactate [R]aerobic performance, heartrate and threshold blood lactate at the aerobic threshold [R]anaerobic heartrate and performance, threshold blood lactate at the anaerobic threshold

There are very many possibilities to calculate or estimate both, the aerobic and the anaerobic threshold. For this guideline we have only defined a few codes to specify the methods of computation and protocols. See subsection 3.2.7 for a coarse overview of our defined codes. For further methods of calculation or performance test protocols, additional codes must be specified. An expression of this element with sample values can be seen in Figure 1. Since our stylesheet has been developed for the Austrian health record and there is currently no automated multi-language support, the output is available in German language only, but a coarse description in English is given in the caption of the figure.

Schwellen- und Maximalwerte			
	Leistung (Watt)	Herzfrequenz (1/min)	Laktat (mmol/l)
Maximalleistung	360	184	12.8
Aerobe Schwelle			
Laktat (2 mmol/l)	209	150	2
Laktat (LTP1)	188	142	1.7
Anaerobe Schwelle			
Laktat (4 mmol/l)	266	168	4
Laktat (LTP2)	268	168	3.9
Herzfrequenz (HRT)	267	168	3.9

Figure 1: An example of the output of our stylesheet (available in German only) for the CDA body element "thresholds and maximum values". The three columns with numbers display values for the actual performance power, the heartrate and the blood lactate level calculated at different performance levels (rows), like maximum level, at a blood lactate of 2 mmol/l, at the individual aerobic threshold (LTP1), at a blood lacate level of 4 mmol/l, at the individual anaerobic threshold (LPT2) and via the heartrate deflection.

3.2.5 Training intervals

Opt	Element	Description
[R]	interval	development of competition
	training	specific endurance
[R]	endurance	mixture of aerobic and anaero-
	method	bic energy supply
	intensive	
[R]	endurance	development of the anaerobic
	method	threshold (endurance perfor-
	medium	mance level)
[R]	endurance	development and stabilization
	method	of fundamental endurance
	extensive	
[R]	endurance	support of recovery process
	method	
	regenerative	

Based on the results of the cardiopulmonary exercise test, sport scientists or doctors are able to suggest training intervals for the patients or athletes. In CDA level 3 we represent these suggested training intervals with the element "referenceRange". The suggested training duration is represented via the element "effectiveTime" with separate values for "high" and "low". In case a training duration is or should not be given for a certain training interval the "effectiveTime" element remains empty. Figure 2 shows some sample values for this CDA body element. Note that the stylesheet also produces some explanations for the values, including literature references for better human readability. These explanations can be seen just beneath the table. Again, this figure is available in German only, but an English description is given its caption.

3.2.6 Raw data

The raw data values section comprises all measured values during the whole cardiopulmonary exercise test. That can well be several hundred values, since e.g. the heartrate is typically measured every 5 seconds, and such tests take about 10 to 20 minutes. Most often, several physical parameters are collected in parallel, also at different intervals. These data are stored differently in CDA level 2 and level 3: we refrain from storing individual values in level 2 – only a single image containing the plots of all parameters is stored, while in level 3 the values of all parameters are coded machine readable.

Traningsmethode	Herzfrequenz	Dauer
Intervalltraining (GB)	>168	
Dauermethode intensiv (EB2)	155 - 168	10 - 45 min
Dauermethode mittel (EB1)	143 - 154	30 - 90 min
Dauermethode extensiv (GLB)	132 - 142	bis über 90 min
Dauermethode regenerativ	<132	bis 30 min
Grundlagenausdauer; aerobes A	lusdauertraining	oilisierung der
Grundlagenausdauer; aerobes A Entwicklungsbereich (EB) - Entw Ausdauerleistungsgrenze); gem Energiebereitstellung Grenzbereich (GB) - Entwicklung Ausdauer; überwiegend anaerot	usdauertraining icklung der anae ischt aerobe und der wettkampfs be Energiebereit	eroben Schwelle d anaerobe pezifischen stellung
Grundlagenausdauer; aerobes A Entwicklungsbereich (EB) - Entw (Ausdauerleistungsgrenze); gem Energiebereitstellung Grenzbereich (GB) - Entwicklung Ausdauer; überwiegend anaerot Das Grundlagenausdauertrainin die vorherrschende Trainingsart.	usdauertraining icklung der anaa ischt aerobe und der wettkampfs be Energiebereit g ²⁾ ist in den Aus Die ideale Zusa r den Freizeitsno	polisierung der eroben Schwell d anaerobe pezifischen stellung sdauersportarte immensetzung uf (nicht für

Figure 2: The element "training intervals" filled with sample values and illustrated via our stylesheet. It gives recommendations in the form of heart rate ranges and training durations for different types of training. The German text beneath the table gives the human reader some explanations of the data above, including e.g. a literature reference. The second and third column shows the suggested heartrate and the duration of the specific training method, respectively. The five rows correspond with the five elements of the table at beginning of section 3.2.5.

According to the general Austrian stylesheet it is possible to include such images in a CDA document. In this case it seems to us, that an adaptation of this general stylesheet would be advisable, since it is not able to display SVG-images (scalable vector graphics). SVGs enable users to zoom in at all levels of highly detailed data without getting a blurred image. Example adaptations that would at least be necessary are given in Listing 1. An example of an included image can be seen in Figure 3.

Opt	Element	Description
[O]	image	a plot of all values is optional,
		since all individual values are
		coded in CDA level 3
[R]	heartrate	individual values of the
		heartrate must be coded in
		CDA level 3
[RO]	spirometric	individual values of the spirom-
	data	etry must be coded in CDA
		level 3, when a spirometry had
		been done
[RO]	blood lactate	individual values of the blood
		lactate must be coded in CDA
		level 3, when blood lacate had
		been measured

3.2.7 PerformanceCDA codes (LCDAC)

Due to the fact that not all relevant examinations can be covered by an existing LOINC code, we had to make up our own codes for certain areas. When performance tests and their results should be comparable, one has to specify exactly what so called "protocol" had been used during the test (e.g. in which step sizes after which duration had the performance been increased?) and which algorithm had been used to calculate the individual thresholds. Since the number of algorithms and protocols is very exhausting, we can only give a coarse categorization of our defined codes here. We divided the codes into the following groups:

Group	Description
10.xx	Heart
20.xx	Oxygen intake
30.xx	Performance
40.1x	Threshold, aerobic
40.2x	Threshold, anaerobic
60.xx	Training recommendations
100.xx	Performance test protocol

To our best knowledge, also other established coding systems like the ICD CPT 94620/94621 code sets only give a coarse picture of which parameters had been obtained but can not included details about the specific realization of the test itself that is necessary to interpret the results correctly. Anyway, these codes could be specified additionally in future versions of this CDA.

4 Discussion

In this article we present the results of a project. The aim of the project was to give an answer to the question how difficult might it be, to define a working CDA report that fulfills the requirements of the Austrian specifications of the nationwide electronic health record called ELGA.

Given the frameworks and existing guidelines from the ELGA GmbH it turned out to be quite simple, as long as you work out a detailed enough specification the data of concern. Experts in this working area turned out to be invaluable helpers, when it comes to define the data needed and also the need of structure within these data. We began by taking e.g. some old – sometimes even handwritten – documents and analyzed them, including hints of sport scientists and doctors while reading the documentation (i.e. to get an explanation of which part of the data is really important).

Once the data and structure is worked out, the single elements can be quite easily defined. Most of the elements we needed to display in a browser later to more or less exactly represent the old documentation, were already contained in the public available CDA-stylesheet. Only one adaptation had to be done from our side, which was necessary to be able to integrate scalable vector graphic (SVG) images in the CDA. Listing 1: In order to be able to insert SVG images (scalable vector graphics) into the document the stylesheet had to be extended with this little XML segment



Figure 3: Example of an image included in the CDA document. Here, e.g. blood lactate (blue) and the heart rate (red) is plotted against the time. One can see the typical increase in both parameters – linear with a little knee for the heart rate and exponential for blood lactate – while increasing performance.

The next steps might be to try to really integrate this report type in the Austrian electronic health record, which would require a real need for this kind of documentation, successful balloting in HL7 work groups, and so on. But this was not the primary goal of this project, as we already stated at the beginning of this discussion.

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