

PROP – A Medical Expert System for Preoperative Testing

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Abstract. Preoperative evaluation is carried out in an inpatient and outpatient way and may easily cause double examinations. This paper deals with the initiation of a medical application, named “Präoperative Befundung“ (PROP) which is applied by clinicians, internists, family doctors and pediatricians since the year 2008 within the framework of an Austrian Reformpoolproject. The aims of the project are the standardization of preoperative evaluation, the prevention of double examinations and unnecessary tests, by a unique Patient-Anamnesis-Matrix. Moreover knowledge discovery about the preoperative process in general and economical optimization for public health insurance companies was focus of the project. How the system exactly works and how it was possible to make medical professionals using it will be explained in the paper. Empirical results from a two year application of PROP within a Reformpoolprojekt in the state of Salzburg, Austria will be demonstrated.

Keywords: Preoperative evaluation, preoperative diagnostic guideline, data analyses.

1 History and Motivation

Patients undergoing surgical procedures have to be evaluated preoperatively. In most of the involved institutions stringent guidelines for preoperative testing are missing. Thus local algorithms based on expert opinion are widely spread. The current process of preoperative evaluation may easily cause double examinations. One reason therefore is a communication gap between inpatient and outpatient medical professionals. To prevent such double examinations and to standardize preoperative evaluation was the main reason to initiate the development of a user-friendly web based preoperative diagnostic guideline (PROP) focusing on the improvement of the preoperative process [1, 2, 3, 4].

The main goals of the project were:

- Standardization and optimization of the preoperative processes
- Economization by reducing the quantity of tests

- Forcing the medical quality in the special sphere of risks
- Efficient usage of resources in the hospital by using outpatient structures
- Optimization of the preoperative procedures: shorter ways for patients, physical and mental stress of older patients and children and
- Knowledge discovery for the preoperative evaluation process in general.

During the start-up period of the project (from 2006 to middle of 2008) a prototype of PROP was implemented and applied by test users. Later, the PROP project team decided to adapt the “ÖGARI guideline” [5] in order to implement a unique Patient-Anamnesis-Matrix within PROP for standardization purposes of the preoperative diagnosis. This guideline has been created by a team named “Präoperative Evaluierung” and defines the standardization and harmonization of preoperative patient evaluation for interior departments in anesthesiology and extra mural institutions. PROP is applied by clinicians, internists, family doctors and pediatricians since the year 2008 within the framework of an Austrian Reformpoolprojekt in the state of Salzburg. The execution of this project and the achievement of its objectives have been evaluated by the Paracelsus Medical University in Salzburg [7, 8].

The following chapters contain a general description of the functionality of the software, special software features and technical information, application details within the Reformpoolprojekt and empirical results during a constant two year application period of PROP.

2 General Functionality of the Software

The web-based preoperative diagnostic application PROP (<http://prop.fh-salzburg.ac.at>) is a “self-explanatory” expert system where medical professionals may input anonymous, patient-related information in order to get a standardized preoperative indication.

A number of 32 parameters classified in 13 categories (type of surgical procedure, ASA-Classifications, lung, metabolism, liver, kidney, coagulation, neurology, oncology, gynecology, drugs, dyspnoea, hematology, heart) of the patients, the patients’ history, and some general information such as demographic measurements, type of public health insurance company and related parameters are requested. For outpatient users, the hospital of referral is also stored. Via a standardized Patient-Anamnesis-Matrix the system generates a preoperative indication based on the input data. As mentioned above, the matrix is based on the 13 categories. The first category, namely types of surgical procedure is itself defined by 5 parameters: minor-, heavy-, adipositas-, major orthopedic- and pulmonary surgery. The other groups except of the group heart which has three different types of cardiac risk factors with 5 subgroups have between 1 and 3 subgroups. Every parameter accords to defined examinations.

The PROP user is able to see a preview list of his activated information and the proposed preoperative tests. After activation of the “finalization” button the data is stored and a print out of the diagnosis is provided containing an anonymous Patient Identification (Pat_ID). The printout is the basis for the preoperative examination and is handed out to the patient. More details about the functionality and features will be explained in the following section.

2.1 Special Software Features and Further Details

The software PROP provides a platform for inhospital and outpatient health professionals, for special users like insurance companies and the PROP administrator. The different users receive selected views and special roles within the system. Medical professionals generate their preoperative tests slightly differently for the inhospital or outpatient application.

PROP Administrator

The PROP administrator is able to automatically perform certain statistical evaluations, like user statistics or details about the diagnosis combinations which were carried out and further descriptive statistics.

Additionally, the administrator is able to generate user identifications and permissions (username, password), certain user group assignments and may define a clear assignment of the symptoms to the necessary examination within the Patient-Anamnesis-Matrix. Via the administrator, the diagnosis guideline changes are entered and can be applied immediately by the users. Thus the users have access to the most recent version of the algorithm.

Patient-Anamnesis-Matrix

The Patient-Anamnesis-Matrix is the basis for the generation of the standardized preoperative evaluation via PROP. It is based on currently 32 parameters which result in the necessary examinations from the derived symptoms which are certain combinations of these parameters (see the introduction in Chapter 2). The matrix was fixed in the year 2008 in the “ÖGARI guideline“ [5].

Public Health Insurance Company User

Every medical professional need to provide the insurance company with the PROP generated Pat_ID to be able to get the corresponding medical fee. For quality management purpose of their service and the ability to countercheck the diagnosis results according to a certain Pat_ID, it is possible for public health insurance company users to insert this ID into a defined interface in the PROP system and to verify the results.

Anonymity and Login of Users/Patients

One of the main requirements of the project was to provide anonymity protection of medical professionals and patients. No user/patient details are stored in the current system. As already mentioned above, the patient is identified via the anonymous Patient Identifier. The medical professionals get their user name and password after the execution of a PROP-workshop at the medical council of Salzburg. From the system it would hardly be possible to find out which of the users applied which patient, only if the finalization date and timestamp is known exactly.

2.2 Procedures for PROP Users

If a user wants to generate a preoperative evaluation using PROP, someone opens a browser with the current URL <http://prop.fh-salzburg.ac.at>. The first page of the application is opened which shows some general information about team members in charge and other participants of PROP. It is then possible to continue the process by signing in. Therefore, it is important that cookies are activated in the browser. After the login, a general page is opened with information for new users about PROP and about the philosophy of the project.

For being able to fill in the anamneses form, the “Start” button in the text or the “Anamneses” link on the left hand side has to be activated. The first part of the questionnaire is opened where general patient information like sex, age, referral to the hospital (only for outpatient area) and to which public health insurance company the patient belongs is queried. Then the user can switch to the next page where information about the “Type of surgical intervention” is asked. It is necessary to choose one selection of the radio button list. As an example, this page from the PROP System is shown in Fig. 1. The continuative pages described in the following are generally structured in the same way. At the next page the “Anamneses” based on the “ASA-Classifications” [5] is asked. The “Explanation” pages which may also be activated from the left menu answer how the classification is defined. If a user inserts incorrect data it is possible to return to the previous page via a special button in order to correct the input. Hereby it should be mentioned that the “Back” button offered from browsers is not the correct way to return, because information could be stored wrongly.

Fig. 1. Example-page from PROP where a user can choose the “Type of surgical intervention”

The next page of the form shows the “Cardial Risk factors” which are categorized in three areas, namely low, intermediary and heavy risk factors. In future versions of PROP this section will be abandoned as guidelines [6] do not use this grading anymore. The “Show Diagnosis” button which can be activated on this last page

completes the anamneses process. The user gets a preview list of all his activated buttons and the resulting preoperative tests which are recommended. The evaluation process may be finished via the “Cancel”, the “Fill in a new form” or the “Finalize” buttons. Only the “Finalize” button generates the Patient Identifier and forces the process to store the date in the system. From this moment the user is not able to change information of the current patient any-more.

As a final step the preoperative evaluation result may be stored or printed out by activating the “Printout” button. Then, a print version of the result will be generated containing the Patient Identifier. Additionally, the referral to the corresponding hospital is given. In the current preoperative process in the state of Salzburg, the medical professional provides the printout to the patient who takes it to the hospital where the preoperative testing is carried out. The medical professional saves the Patient Identifier and provides it to the public health insurance company. The saving process of the results and the corresponding ID can be easily carried out locally on every computer with HTML, but cannot be opened again by the user via the PROP system. Otherwise, data security and transparency of the user could be violated.

2.3 Technology and Infrastructure

The software is written in the programming language C#¹. As development platform Microsoft Visual Studio 2008¹, Microsoft SQL Server 2008¹ as database is used. The current PROP system is running on a Windows 2008 Server¹. The backup has a size of 2 Gigabytes which currently contains about 40 000 patient results and user information.

The server is located at the Salzburg University of Applied Sciences and provides online access for the PROP users. Additionally a virtual private network (VPN) connection via a Cisco² PIX firewall is provided in order to allow outpatient medical professionals to apply PROP using their e-Card system³. It has to be mentioned that the main part the PROP users connect to the application via the Internet. Fig. 2 exhibits the current architecture of the system.

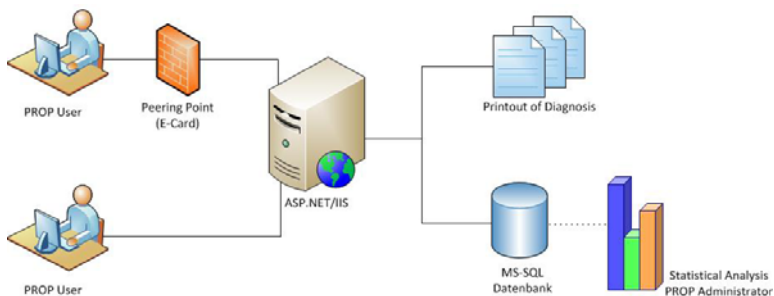


Fig. 2. Architecture of the PROP system during the period of the Reformpoolprojekt

¹ <http://www.microsoft.com/> (Jul. 2011)

² <http://www.cisco.com/> (Jul. 2011)

³ <http://www.peeringpoint.at/> (Jul. 2011)

Consortium and license holder of PROP

Currently, the owner of the PROP license is the SAGES KV - a union of the Salzburger Gesundheitsfonds (SAGES <http://www.salzburg.gv.at/sages>) and the public health insurance organization, i.e. the Krankenversicherungsträger (KV) in Salzburg.

Until the end of the year 2011 the project will be applied as an extended form of the Reformpoolprojekt in Salzburg. The Austrian countries Burgenland, Lower Austria and Upper Austria are also testing the software since the beginning of this year. Further members of the PROP project are:

- the Austrian Medical Chamber (<http://www.aerztekammer.at/>) as a part of the development team and provider for the training workshops for medical professionals;
- the Paracelsus Medical University (<http://www.pmu.ac.at>) where the external evaluation [7] of the Reformpoolprojekt was carried out;
- the Medical Center of Salzburg (SALK <http://www.salk.at/>) with the Department of Anesthesiology, Perioperative Medicine and Intensive Care Medicine as a part of the development team;
- the Austrian Society of Anesthesiology, Resuscitation and Intensive Care Medicine (ÖGARI <http://www.oegari.at/>);
- the National Health-Insurance of Austria (<http://www.sozialversicherung.at/>);
- the Salzburg University of Applied Sciences (<http://www.fh-salzburg.ac.at/>) where the software was developed and hosted during the project phase.

3 Empirical Results

This section contains first results from an empirical analysis of a constant two year application of PROP during the final period within the Reformpoolprojekt in Salzburg, from March 2009 to March 2011.

Currently, 403 users are employing the application and are assigned to certain roles (compare Table 1). In Salzburg seven in-hospital, 362 outpatient members and five users for public health insurance companies have access to the role-adapted system. Other users like the PROP administrator, four test users for Lower Austria and eight for Burgenland are implemented as well. Sixteen other test users are installed in order to provide temporary accesses for interested organizations.

Table 1. Current number of users listed in roles

Number	Role names
1	PROP administrator
5	Health insurance company users
7	Inhospital users Salzburg
28	Test users for Burgenland (8) and Lower Austria (4) and others
362	Outpatient users in Salzburg

The following statistical analyses are carried out using the software SPSS 18.0.0⁴. In Table 2, the patient quantities and frequencies applied by PROP are shown per quarter. Within the two year period a total number of 22 646 preoperative evaluations are stored. The first quarters contain between 2 400 and about 3 900 patients. In last year's 2nd and 3rd quarter the number of evaluations is significantly lower, since in-hospital and outpatient users applied a smaller number of patients. The reason therefore is that the external evaluation period of the Reformpoolprojekt finished at this time and therefore in-hospital users stopped their trial execution of PROP. At the beginning of 2011 these users started the application of PROP again. Table 3 below shows the amount of applied patients for the in-hospital and outpatient case.

Table 2. PROP application frequencies during a two year period

Quarterly Division	Year	Period	Absolute frequency	Relative frequency
2 nd Mar. – 31 st May	09	Q1_1	3 853	17,0%
1 st Jun. – 31 st Aug.	09	Q2_1	3 266	14,4%
1 st Sept. – 30 th Nov.	09	Q3_1	3 887	17,2%
1 st Dec. – 28 th Feb.	09/10	Q4_1	2 856	12,6%
1 st Mar. – 31 st May	10	Q1_2	2 367	10,5%
1 st Jun.– 31 st Aug.	10	Q2_2	1 737	7,7%
1 st Sept. – 30 th Nov.	10	Q3_2	2 163	9,6%
1 st Dec. – 2 nd Mar.	10/11	Q4_2	2 517	11,1%
Total			22 646	100,0%

Table 3. Frequencies of patients in the outpatient and in-hospital area for the two year period

Grouping	Frequency	Percentage
outpatient	14 689	64,9%
in-hospital	7 957	35,1%
Total	22 646	100,0%

In Fig. 3 an error bar plot (99% confidence interval) of the user access times in minutes (time between login and preoperative evaluation result in the database) divided into the number of patients in the outpatient and in-hospital area is shown. In the outpatient area the users need less than 5 minutes for finalizing one patient and the estimation of the average access times is very accurate. A slightly decreasing trend is visible during the observation period. Because of the fact that outpatient users apply trainings before getting their PROP access, the time for preoperative evaluation via PROP is continuously low. In comparison, the in-hospital users need time to learn how to apply the system. Furthermore, the login session of in-hospital users is longer than in the outpatient case in general.

⁴ <http://www.ibm.com/software/analytics/spss/> (Jul. 2011)

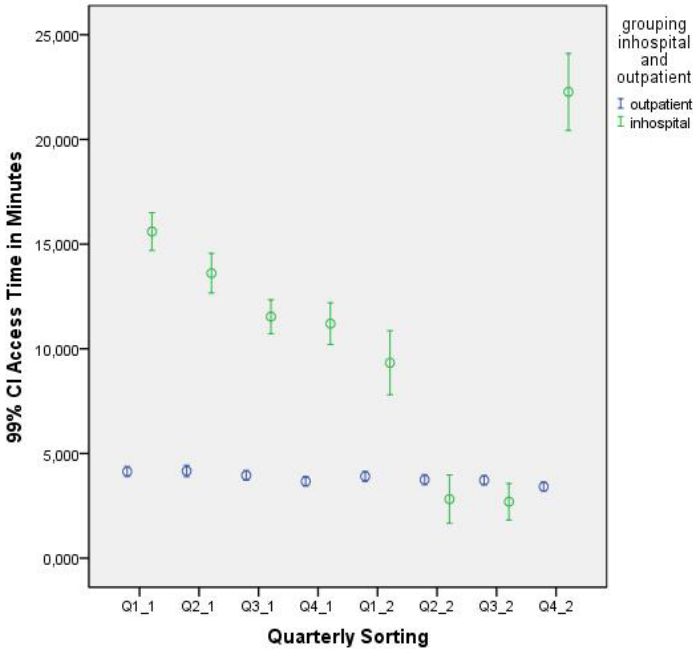


Fig. 3. Access times for inpatient and outpatient PROP users (99% confidence intervals)

In the inpatient case there seems to be more time provided for the evaluation process in general. In the first five quarterly periods there is a continuous decrease of the access time which demonstrates how the users learned to deal with the system. In the 6th and 7th quarter the access time is very low whereas in the 8th quarter the average time increased rapidly from about 5 minutes up to over 20 minutes. As already mentioned above, this is due to the fact that the period for external evaluation of the PROP project finished at this time and therefore inpatient users stopped the trial execution of PROP. At the beginning of 2011 the usage of PROP was started again by new inpatient users and therefore the access times obviously increased.

In Fig. 4 the frequencies for the type of surgical intervention for the whole observation period are shown as bar chart. Table 4 contains the corresponding absolute quantities. As can be seen from the chart, the number of female patients is significantly higher than those of male patients except in the case of “lung surgery”. Minor surgeries are carried out for female patients about 10% more often than for male patients. The reason therefore may be that women take part in preventive medical examinations to a greater extent. In relation to the other type of surgical interventions, the “adipositas surgery” is carried out rarely, but for female patients 50% more often than for masculine ones. This surgical intervention is in the state of Salzburg only offered in the hospital of Hallein.

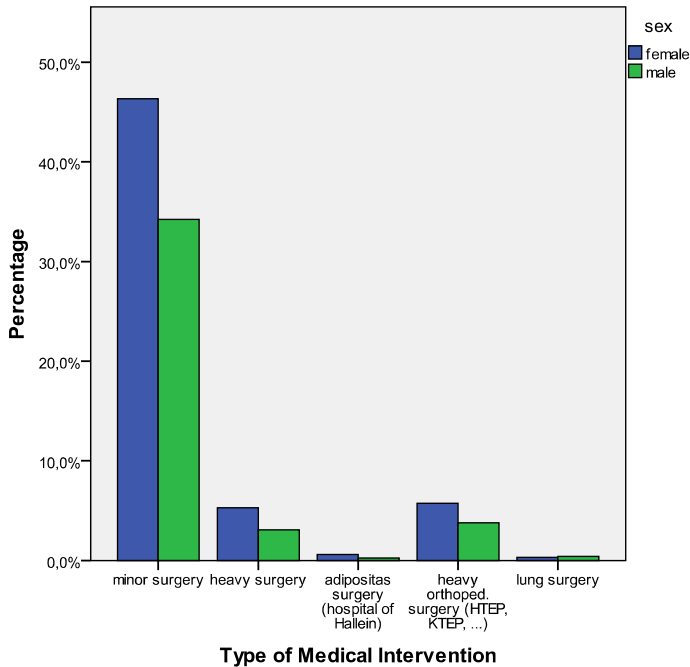


Fig. 4. Type of medical intervention for female and male patients for the period of two years

Table 4. Type of operation in absolute and relative frequency for male/female patients

Type of Operation	Frequency	Percent	Men	Women
minor surgery	18 217	80,4%	7 738	10 479
heavy surgery	1 892	8,4%	698	1 194
adipositas surgery (hospital of Hallein)	195	0,9%	56	139
major orthoped. surgery (HTEP, KTEP, ...)	2 149	9,5%	851	1 298
pulmonary resection	164	0,7%	92	72
Total	22 617	100,0%	9 435	13 182

Fig. 5 shows an overview of the number of PROP patients belonging to a certain public health insurance company. The corresponding numerical values are given in Table 5. In the latter table the English denominations with German abbreviations in brackets are given. The abbreviations stand for Versicherungsanstalt öffentlich Bediensteter (BVA), Salzburger Gebietskrankenkasse (SGKK), Sozialversicherungsanstalt der gewerblichen Wirtschaft (SVA), Sozialversicherungsanstalt der Bauern (SVB) and Versicherungsanstalt für Eisenbahnen und Bergbau (VAEB).

Most of the patients (82%) in Salzburg are members of the SGKK, of which 32% are male and 50% female patients. A number of 8.5% of all patients in PROP are members of the BVA and the remaining 9.2% are members of SVA, SVB or VAEB.

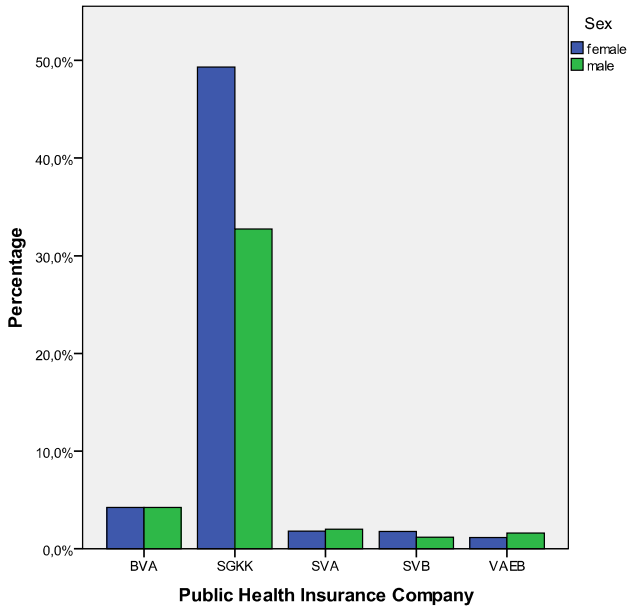


Fig. 5. Number of female and male patients per public health insurance company

Table 5. A list of public health insurance companies and their patient frequencies

Public Health Insurance Company	Frequency	Percentage	Men	Women
Insurance institution of public servants (BVA)	1 917	8,5%	958	959
Regional medical insurance of Salzburg (SGKK)	18 581	82,0%	7 411	11 170
Social Security institution of the industrial economy (SVA)	860	3,8%	451	409
Social Security Institution of the farmers (SVB)	668	2,9%	266	402
Insurance institution of railway and mining (VAEB)	620	2,7%	361	259
Total	22 646	100,0%	9 447	13 199

4 Summary and Future Perspective

From the project start up to now, about 40 000 patients have been preoperatively evaluated using the web application PROP which was applied within a Reformpoolprojekt in the state of Salzburg, Austria from 2008 to 2011. The evaluation algorithm of PROP is based on the “ÖGARI guideline” for preoperative testing [5]. Application experience and evaluation of the project have demonstrated the economic potential of this standardized preoperative procedure and the prevention of double examinations was verified [1, 2, 3, 7, 8].

Since then, the usage of the software is well accepted by the PROP users and the usage is reported to be very easy. The acceptance of the application was constantly

improved due to the introduction and information process by the PROP consortium (Sect. 2.3) and the training workshops organized by the Austrian Medical Chamber. The team at the Salzburg University of Applied Sciences had to deal with requests from the outpatient medical professionals via telephone but mainly with very easy duties such as password resets, login support and general questions on the IT infrastructure of their medical practice, such as support for printout from a web browser, i.e. questions which are not directly related to with PROP. Therefore, the system was provided with small services for user support in order to answer general technical questions like “How and where can I print out the diagnosis?”, “How may I reset username and password?”, “How is it possible to save the password permanently in the browser?” and so on.

The goal of the present paper is to provide a technical description of the PROP system and to demonstrate empirical results from a constant application PROP during a two year period within the Reformpoolprojekt. These results contain general patient frequencies, types of medical interventions, insurance classifications and important differences between female and male patient behavior. The user access times (time between login and preoperative evaluation result) demonstrate the learning effect of the application of PROP in the in-hospital and outpatient case.

The application of PROP during the Reformpoolprojekt phase also showed some suggestions for possible future adaptations. In Fig. 6 recommended further extensions for an improved PROP system are visualized. In order to provide a connection to medical information systems, a universal interface which allows a standardized data transfer is necessary. The export of the diagnoses may be realized in the format HL7 (Health Level 7) which is a standard medical protocol. The diagnosis itself could be stored in the system in form of Extensible Markup Language (=XML) files which offer a standardized data format and well defined options for data exchange and -processing.

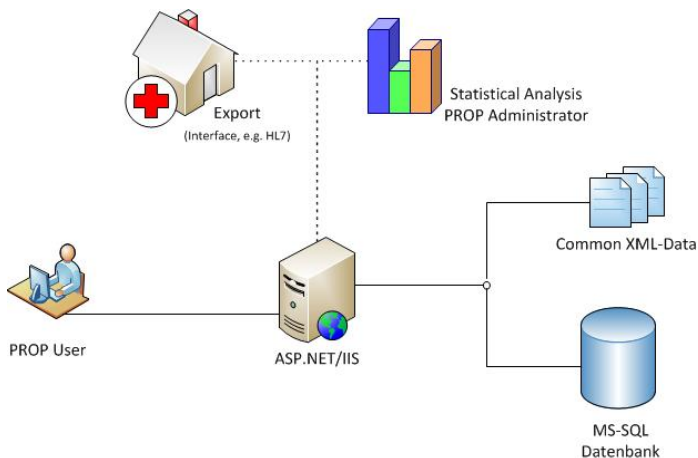


Fig. 6. Recommended architecture for a future PROP system

Acknowledgment. The authors would like to thank all colleagues from the organizations involved in the execution and development of the project (see Sect. 2.3) especially Dr. Beate Stolzlechner from SAGES for her support. The first author is supported by the FWF project L526-B05.

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