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Before and After Study

Lasagna plots to visualize results in surgical studies

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HIGHLIGHTS

- A lasagna plot is a new method to graphically display longitudinal data.
- The lasagna plots gave a clear overview of multiple end points after surgical interventions.
- The lasagna plots demonstrated new observations and improved the interpretation of the results.

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ABSTRACT

Background: A lasagna plot is a graphical tool that can display multiple longitudinal outcomes. To our knowledge, lasagna plots have not been used in publications of surgical studies before. The objective of this study was to demonstrate the results of surgical randomized controlled trials (RCTs) with lasagna plots in order to assess whether this can lead to new observations of the data presented in the original studies.

Material and Methods: Lasagna plots were created with R for an RCT comparing endovascular and open repair for patients with a ruptured abdominal aortic aneurysm (AJAX trial), an RCT comparing laparoscopy or open surgery combined with either fast track or standard care for patients with colon cancer (LAFA trial) and an RCT comparing preoperative biliary drainage and early surgery for patients with pancreatic cancer (DROP trial).

Results: Regarding the AJAX trial, the original article had reported the rate of outcomes at 30 days after repair in two tables. The plots additionally demonstrated the moments of occurrence, increase and decrease of multiple outcomes such as renal replacement therapy and occurrence of death within one plot. These observations were not presented in the original article. The lasagna plots of the LAFA and DROP trial revealed similar new observations on multiple longitudinal outcomes.

Conclusion: By revealing new observations of the previously published data, lasagna plots generate new hypotheses and theories regarding the outcomes. As such, lasagna plots may be a useful addition to traditional tables and figures and could improve the interpretation of results.

1. Introduction

Scientists usually use graphical visualizations such as pictures and diagrams to demonstrate findings. After all, it is widely known that graphics help in delivering and interpreting a clear message [1]. In addition, it is believed that graphics are easier to remember than words and numbers.

As new technologies develop, numerous scientific journals and institutions have encouraged graphics in scientific communications, with the aim of improving information transfer between scientists [2]. Also in daily clinical practice, patient information is increasingly being visualized with charts and figures in electronic patient files. Despite these developments, medical doctors and surgeons still do not commonly use graphics tools to report their most important research findings in scientific publications. Currently, many studies report their outcomes in large and rather incomprehensive tables that do not always have the ability to show the context or chronological patterns of outcomes.

A lasagna plot is a graphics tool that can display longitudinal

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data [3]. The plot can be used to visualize multiple outcomes in the course of time. Studies have used lasagna plots to report on a variety of longitudinal outcomes such as sleeping patterns, the follow-up of patients with breast cancer, and on patterns of bacterial flora changes [4–7]. The lasagna plots added to the traditional analyses by revealing trends in the course of time, which are hard to present with numbers and point estimates. The plots can be created with different statistical programs such as R (R Foundation for Statistical Computing, Vienna, Austria) and SAS® (SAS Institute Inc, Cary, NC, USA) [8].

To our knowledge, lasagna plots have not been used to visualize outcomes after surgical interventions. However, these plots could be of additional value since surgical studies report on multiple often interrelated outcomes which may occur at different moments in time. If lasagna plots could reveal additional observations than traditional tables and graphs, this could generate new questions and hypotheses regarding surgical research or treatment strategies.

The objective of this study was to demonstrate the results of surgical randomized controlled trials (RCTs) with lasagna plots in order to assess whether this can lead to new observations of the data presented in the original studies.

2. Material and methods

2.1. The trials

We created lasagna plots for three RCTs [9–11] from the Department of Surgery in the Academic Medical Center, Amsterdam, The Netherlands. Characteristics of these trials (AJAX, LAFA and DROP) are listed in Table 1. The AJAX trial (ISRCTN 66212637) randomized patients with a ruptured abdominal aortic aneurysm (RAAA) between endovascular aneurysm repair (EVAR) and open repair (OR) [9]. The LAFA trial (NTR 222, www.trialregister.nl) randomized patients with colon cancer between laparoscopic or open segmental colectomy combined with either fast track or standard care, resulting in four treatment groups [11]. The DROP trial (ISRCTN 31939699) randomized patients with obstructive jaundice caused by cancer of the pancreatic head to either preoperative biliary drainage (PBD) or early surgery [10]. The trials were conducted in accordance with the Declaration of Helsinki and were approved by Medical Ethics Committees. All included patients gave written informed consent.

2.2. Lasagna plot creation

Original raw data from the three trials were used to create the lasagna plots. The lasagna plots were created with R. Data were transformed into lasagna plots using three steps:

2.2.1. Spreadsheet file

Firstly, for each trial, original study data were transformed into a spreadsheet file in IBM SPSS Statistics version 23 (SPSS Inc., Armonk, NY, USA), which described the status of patients on every follow-up day. In the spreadsheet file, every row represented a patient and every column represented a follow-up day. Patient status on every day was categorized into one of the selected outcomes. The spreadsheet file that was used for the creation of Fig. 1 is attached to this manuscript as Supplementary Material S1.

2.2.2. Unsorted plot

Secondly, the spreadsheet file was transformed into an unsorted lasagna plot using R with previously described coding [3]. The used R codes for the creation of Fig. 1 are attached to this manuscript as Supplementary Material S2. Fig. 1A is an example of an unsorted lasagna plot of ten randomly selected patients from the AJAX trial. The horizontal axis of the plot represents the time after the intervention and the vertical axis represents the patients. Thus, every horizontal layer represents the follow-up of an individual patient in the course of time.

2.2.3. Within-column sorted plot

Finally, within-column sorting was applied to create the lasagna plots as demonstrated in this current study. This formatting results in the loss of horizontal layers representing single patients, but reveals group-level patterns of outcomes (Fig. 1B). By sorting severe outcomes low in the plot, and favorable outcomes high, the group-level patterns are visualized. In addition, we calculated the surface area of each outcome to quantify the accumulation of outcomes over time.

2.3. Variables in the lasagna plots

In theory, any outcome can be included in a lasagna plot. For the purpose of visualizing the trials, we included the primary and some of the secondary endpoints of the trials. The number of presented follow-up days was based on the course of outcomes in each trial. The lasagna plots of the AJAX trial included the following outcomes: serum creatinine during admission, temporary renal replacement therapy during admission, discharge, and death. Serum creatinine served as a marker of renal function and was included in the lasagna plot because a subsequent study showed that acute kidney injury was more prevalent than expected [12]. The lasagna plots of the AJAX trial consisted of the first fifteen days after intervention. The lasagna plots of the LAFA trial included diets during admission (nil per os, clear liquid, liquid, full oral), discharge, readmission, and death within the first five postoperative days. The lasagna plots of the DROP trial included PBD-related complications, surgery-related complications, admission for surgery without complication, discharge after an uneventful course without complications, discharge after a complicated course (either a PBD- or surgery-related complication), and death. The lasagna plots of the DROP trial consisted of the first 120 days after randomization.

Table 1
Characteristics of the three surgical randomized controlled trials.

	AJAX trial	LAFA trial	DROP trial
Period	2004 – 2011	2005 – 2009	2003 – 2008
Participants	Patients with ruptured abdominal aortic aneurysm	Patients with colon cancer	Patients with obstructive jaundice caused by cancer of the pancreatic head
Number of randomized participants	116	400	202
Number of centers	3 hospitals	9 hospitals	13 hospitals
Treatment arm 1	Open repair	Laparoscopy + fast-track	Preoperative biliary drainage
Treatment arm 2	Endovascular repair	Laparoscopy + standard care	Early surgery
Treatment arm 3	–	Open surgery + fast-track	–
Treatment arm 4	–	Open surgery + standard care	–
Primary endpoint	Composite: Death + severe complications at 30 days	Total postoperative hospital stay	Serious complications within 120 days