BMJ Open

Endoscopic third ventriculostomy for adults with hydrocephalus: creating a prognostic model for success: protocol for a retrospective multicentre study (Nordic ETV)

Sondre Tefre ,[1] Alexander Lilja-Cyron ,[1] Lisa Arvidsson,[2] Jiri Bartek ,[2] Alba Corell ,[3] Axel Forsse ,[4] Andreas Nørgaard Glud ,[5] Sami Abu Hamdeh ,[6] Frederik Lundgaard Hansen,[5] Antti Huotarinen ,[7] Conny Johansson ,[8] Olli-Pekka Kämäräinen ,[7] Tommi Korhonen ,[9,10] Anna Kotkansalo ,[11] Nadia Mauland Mansoor ,[12] Eduardo Erasmo Mendoza Mireles,[13,14] Rares Miscov ,[15] Sune Munthe ,[4] Henrietta Nittby-Redebrandt ,[16] Nina Obad,[17] Lars Kjelsberg Pedersen,[18] Jussi Posti ,[11] Rahul Raj ,[19] Jarno Satopää ,[19] Nils Ståhl,[16] Sami Tetri ,[9,10] Lovisa Tobieson ,[20] Marianne Juhler [1]

To cite: Tefre S, Lilja-Cyron A, Arvidsson L, *et al*. Endoscopic third ventriculostomy for adults with hydrocephalus: creating a prognostic model for success: protocol for a retrospective multicentre study (Nordic ETV). *BMJ Open* 2022;**12**:e055570. doi:10.1136/bmjopen-2021-055570

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-055570).

Received 20 July 2021
Accepted 15 December 2021

Check for updates

© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to
Dr Sondre Tefre;
sondre.tefre@regionh.dk

ABSTRACT

Introduction Endoscopic third ventriculostomy (ETV) is becoming an increasingly widespread treatment for hydrocephalus, but research is primarily based on paediatric populations. In 2009, Kulkarni *et al* created the ETV Success score to predict the outcome of ETV in children. The purpose of this study is to create a prognostic model to predict the success of ETV for adult patients with hydrocephalus. The ability to predict who will benefit from an ETV will allow better primary patient selection both for ETV and shunting. This would reduce additional second procedures due to primary treatment failure. A success score specific for adults could also be used as a communication tool to provide better information and guidance to patients.

Methods and analysis The study will adhere to the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis reporting guidelines and conducted as a retrospective chart review of all patients≥18 years of age treated with ETV at the participating centres between 1 January 2010 and 31 December 2018. Data collection is conducted locally in a standardised database. Univariate analysis will be used to identify several strong predictors to be included in a multivariate logistic regression model. The model will be validated using K-fold cross validation. Discrimination will be assessed using area under the receiver operating characteristic curve (AUROC) and calibration with calibration belt plots.

Ethics and dissemination The study is approved by appropriate ethics or patient safety boards in all participating countries.

Trial registration number NCT04773938; Pre-results.

Strengths and limitations of this study

- Large consecutive sample of adult patients treated with endoscopic third ventriculostomy from multiple neurosurgical centres in the Nordic countries.
- Goal of creating a prognostic model to aid patient selection and guidance.
- Subject to the inherent limitations of a retrospective study.
- Similar healthcare systems in the Nordic countries, and model will need validation in other regions to ensure generalisability.

INTRODUCTION

The most common treatment for hydrocephalus is a ventriculoperitoneal shunt (VPS) to divert excess cerebrospinal fluid (CSF) from the ventricles to be absorbed in the peritoneum. The treatment can be applied in different aetiologies of hydrocephalus, but there is a high complication risk both short and long term.[1–3] In 2017, Merkler *et al* performed a retrospective review of 17 035 adult patients who had undergone their first VPS surgery for hydrocephalus.[2] They report that one-third (33.4%) of the patients experienced at least one complication during the follow-up period (3.9 years), and 22% required a shunt revision. Twenty-one per cent of the complications occurred within the first year. Based on 683 adult patients, Reddy

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.

et al reported that 32% experienced shunt failure, with 74% occurring within 6 months.[3]

Endoscopic third ventriculostomy (ETV) is an alternative treatment option creating a passage between the ventricles and the subarachnoid space by perforating the floor of the third ventricle.[4] It is minimally invasive and leaves no mechanical foreign body behind, thereby avoiding many of the implant complications associated with VPS.[5]

The overwhelming majority of research on ETV is conducted in paediatric or mixed paediatric/adult populations.[4 6] In 2009, Kulkarni *et al* created the ETV Success Score (ETVSS) to predict the outcome of ETV treatment in children.[7] The ETVSS consists of three factors: age, aetiology and shunt history. Based on these factors, a score from 0 to 90 is given, representing the predicted probability of successful ETV outcome 6 months postoperatively.

As the ETVSS is based on paediatric populations and the age differentiation stops after the patient has reached 10 years, 50 out of a possible 90 points are given if the patient is more than 10 years old, making this parameter in the ETVSS redundant when used in adults. Furthermore, the ETVSS does not include several common aetiologies for adult hydrocephalus such as idiopathic and secondary normal pressure hydrocephalus (NPH), subarachnoid haemorrhage (SAH) and long-standing overt ventriculomegaly in adults (LOVA). Previous shunt treatment seems to play an important role in adults as well, but only minimally influences the paediatric score.[8] Isaacs *et al* reported an overall success rate of 80%. Patients treated with ETV as the primary treatment had a better success rate than previously shunted patients, at 87% and 65%, respectively.[9] Waqar *et al* showed similar results with 79% success in the primary treatment group and 55% secondary to shunt treatment, at 10 years follow-up of 190 patients.[10]

Radiological findings are not included in the ETVSS, and although most radiological signs of obstruction are subjective evaluations based on the observer's experience, some quantifiable signs have been identified. Dlouhy *et al*[11] and Kehler *et al*[12] found downward bowing of the third ventricular floor to be a strong predictor of ETV success. The bowing was measured by placing a line through the chiasma to the top of the mesencephalon or the mamillary bodies. Downward bowing was defined as inferior displacement of the third ventricle floor below this line.

Although there are a few studies analysing long-term ETV survival in adults,[4 9 10] most are in paediatric[13–19] or mixed populations.[20–26] The existing long-term series on adult patients show most failures occurring shortly after the procedure although late failures are reported.[9 10] Kaplan-Meier curves for ETV survival have an initial steep decline, followed by a gradual fall-off before it seems to stabilise with few failures after a certain point. Determining the composition of patient characteristics, these three different parts of the curve could provide insight into how different patient categories respond to ETV. The initial fall-off is hypothesised to represent patients without benefit from the procedure as well as significant symptoms requiring early reoperation. The second gradual decline might be caused by patients in which the ETV was ineffective from the beginning, but with more chronic symptomatology giving more time to evaluate the effect before reoperation. The failures occurring in the stable part of the curve might represent initial success with a late closure of the stoma or an absorption problem occurring later.

Main hypothesis

A prognostic scoring system for adult ETV can be created based on patient demographics, symptomatology, aetiology, shunt history and radiological findings.

Secondary hypotheses

- Age is still a relevant factor but has the inverse effect in adults with less successful outcomes with older age.
- Hydrocephalus aetiology and shunt history have prognostic value but must be recalibrated to reflect the spectrum of hydrocephalus conditions in adults.
- It is possible to develop a radiological hydrocephalus classification and scoring system providing additional prognostic value.
- There are different characteristics in the failures occurring during the different phases seen on the Kaplan-Meier survival curve.

Rationale

With ETV becoming an increasingly widespread treatment for adult hydrocephalus,[9 27] there is a need for a new prognostic model specific for this patient population. The ability to predict who will benefit from an ETV will allow better primary patient selection both for ETV and shunting. This would reduce additional second procedures due to primary treatment failure, and possibly prevent further unnecessary procedures. A success score specific for adults could also be used as a communication tool to provide better information and guidance to patients.

Study goals and objectives

The purpose of this study is to create a prognostic model to predict the short-term success of ETV for adult patients with hydrocephalus.

Specific aims for this research project is to:

1. identify factors associated with both success and failure of ETV in adults, to establish a prognostic model.
2. report on ETV success rates, complications and survival in adult patients at the participating centres.

METHODS AND ANALYSIS

Study design

This is an observational study and will be conducted as a retrospective review of electronic patient charts. The study will adhere to the TRIPOD guidelines in the development of the prediction model.[28] A multivariate logistic

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.

regression model will be used to identify prognostic factors for success of ETV treatment. This model is expected to be simplified to include only three to four strong predictors to make it useful in daily clinical practice.

Population

The study will include all patients ≥18 years of age treated with ETV at the 19 participating neurosurgical centres in Norway, Sweden, Denmark and Finland from 1 January 2010, to 31 December 2018. Patients are excluded if permanent intraventricular foreign bodies are left behind after the ETV procedure, such as shunts or stents, as they might influence outcome following ETV. Temporary external ventricular drains, ICP-monitoring probes or ligated shunts where the ventricular drain is removed, are not excluded.

Data collection and monitoring

Each of the participating centres will be responsible for the data collection in a standardised database, containing the following information: (see Supplemental material file 1) for full list of variables):

- Date of birth, sex.
- Aetiology of hydrocephalus: Haemorrhage (SAH or intraventricular haemorrhage (IVH)), infection or carcinomatosis, tumour or cyst (location), trauma (type of traumatic lesion), malformations (type of malformation), NPH or idiopathic intracranial hypertension (IIH).
- Radiological investigation: the radiologist's description will be used to determine the presence of a visible obstruction. Specific signs and measurements (see online supplemental material 1) will be recorded based on representative images uploaded to the database. The images will consist of one mid-sagittal, coronal (at the level of the posterior commissure) and axial (at the level of the frontal horns widest point). These images will be reviewed in bulk, with assistance from the Department for Neuroradiology in Copenhagen.
- Previous shunt treatment: number of revisions, cause of malfunction, year of first shunt.
- Preoperative symptoms: acute and chronic symptoms, including preoperative GCS.
- Surgical details: date, perioperative observation, concurrent and following procedures.
- Complications: perioperative and postoperative complications, length of stay, permanent morbidity and mortality.
- Follow-up: clinical status at first postoperative follow-up at 3–12 months, as well as most recent follow-up for ETV durability. Clinical improvement will be registered based on the records from the first available follow-up. If the patient's chart leaves any doubt when registering if the patient's symptoms improved postoperatively, it should be registered as 'not improved'.

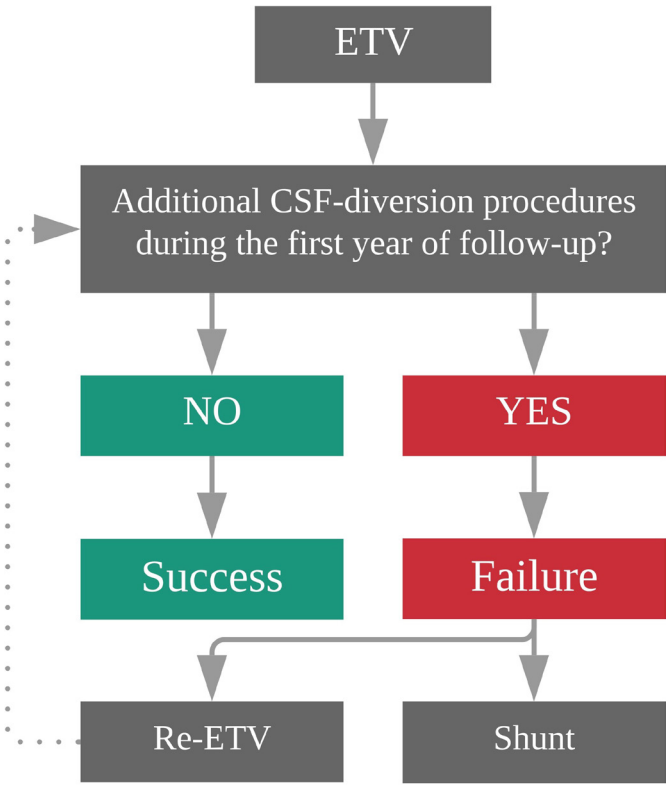

Figure 1 Definition of short-term endoscopic third ventriculostomy (ETV) success. Results of re-ETV is not counted in the overall success rate. CSF, cerebrospinal fluid.

All ETVs performed at the participating centres will be entered in the database and then included or excluded based on the inclusion/exclusion criteria. Reason for exclusion will be registered.

Definition of ETV-success

Success is defined as no need for further CSF-diversion procedures within the first year of follow-up (figure 1). Patients in whom the ETV was deemed ineffective before the patient was discharged or where a second procedure was performed during the same admission are included in the registry. Implantation of ICP-monitoring equipment does not render the ETV unsuccessful, unless it is followed by CSF diversion. Patients undergoing repeat ETV are counted as failures when calculating the success rate, but results are registered in order to determine the efficacy of re-ETVs. Additional CSF-diversion procedures will be registered for the entire observation period (beyond the first year) to determine long-term ETV survival.

Sample size

Sample size was calculated using the 'pmsampsize' package in R by Riley *et al*.[29] The closest analogous predictive model is the ETVSS by Kulkarni *et al*[7] and the estimation was created using prevalence and C-statistic from this model. This resulted in a minimum sample size of 429 patients, for a predictive model using 5 variables. There is no upper limit, as more patients would give a

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.

better foundation for the prediction model, especially in patients with aetiologies rarely treated with ETV such as iNPH or hydrocephalus caused by infection or SAH. Approximately 220 adult ETV patients have been identified in Copenhagen 2010–2017. Cooperation between several centres should easily provide the minimum required sample size and the necessary power to create a robust prognostic model. An estimate of at least 250 ETV procedures from each of the participating countries would result over 1000 patients.

Follow-up

This is a retrospective study, and thus limited to the information documented in the patient records.

Clinical status is registered at first postoperative follow-up at 3–12 months, as well as most recent follow-up where ETV durability can be assessed. The study population will be followed up on in the future to determine long term outcomes, but this is beyond the scope of this study.

Data management and statistical analysis

Patient demographics, hydrocephalus aetiology and shunt history, as well as complications, will be summarised using descriptive statistics. The patient's symptoms are categorised as 'improved' or 'not improved' following treatment. If the patient requires subsequent CSF diversion procedures the ETV is considered a failure. Each of the proposed predictors is analysed in a univariate statistical analysis and are subsequently included in a multivariate logistic regression model to construct a unified prediction model. Statistical significance is defined at $p<0.05$. The model will be validated using K-fold cross validation. Discriminative ability will be assessed using area under the receiver operating characteristic curve (AUROC) and calibration using calibration belt plots.[30] Significant missing data will be handled using multiple imputation.[31] Time to ETV failure will be analysed using Kaplan-Meier curves.

Outcome variables

Primary outcome

- Short-term ETV success rate defined as no need for further CSF-diversion procedures within the first year of follow-up.

Secondary outcomes

- Rate of clinical improvement at first follow-up following ETV, and correlation with need for eventual CSF diversion.
- Time to failure: examined using Kaplan-Meier analysis.
- Complications, all registered intraoperative and postoperative complications and deficits, assessed up to 3 months postoperatively.

Creating a prognostic model for adults based on a large population will improve the ability to predict the outcome of ETV and offer the appropriate treatment. The goal is to increase the benefit for patients and reduce the number of unnecessary procedures. The model will need to be tested in a future prospective study. And a later follow-up with the population in this study to report long term outcomes.

Project status

At the time of the submission of the protocol, data collection has started at all participating sites.

Duration of the project

Data collection is expected to be completed by May 2022, data analysis during Q2 of 2022 and publication Q3 2022.

Patient and public involvement

The study is observational based on retrospective data. No patients were involved in the design or implementation of the study.

Data sharing plan

The study is conducted as part of the Nordic Young Neurosurgeons Research Collaborative (NYNReC). Data are available on reasonable request. Interested parties must apply in writing through nynrec.org including plan for analysis and dissemination of findings. Application will be evaluated by the NYNReC Committee and study lead. A request for access may be declined if the proposal lacks clarity or a satisfactory methodology.

SAFETY AND ETHICAL CONSIDERATIONS

The study is retrospective, based on electronic patient records, and will not intervene in patient treatment in any way. The main concern is data protection and privacy, and the study is approved by appropriate ethics or patient safety boards in all participating countries:

- Norway: Regional Committees for Medical and Health Research Ethics (REC): 90 565.
- Sweden: Swedish Ethical Review Authority: 2020-00874.
- Denmark: Danish Patient Safety Authority: 3-3013-2335/1 and 31-1522-58; Knowledge Center for Data Reviews (Videnscenter for Dataanmeldelser): P-2020-569.
- Finland: FINDATA—Social and Health Data Permit Authority: THL/2288/14.02.00/2000.

The study has been registered on clinicaltrials.gov under prior to the start of data collection.

Author affiliations
[1]Department of Neurosurgery, Rigshospitalet, Copenhagen, Denmark
[2]Department of Neurosurgery, Karolinska University Hospital, Stockholm, Sweden
[3]Department of Neurosurgery, Sahlgrenska University Hospital, Goteborg, Sweden
[4]Department of Neurosurgery, Odense University Hospital, Odense, Denmark
[5]Department of Neurosurgery, Aarhus University Hospital, Aarhus, Denmark
[6]Department of Neurosurgery, Uppsala University Hospital, Uppsala, Sweden
[7]Department of Neurosurgery NeuroCenter, Kuopio University Hospital, Kuopio, Pohjois-Savo, Finland
[8]Department of Neurosurgery, University Hospital of Umeå, Umeå, Sweden
[9]Department of Neurosurgery, Oulu University Hospital, Oulu, Finland
[10]Research Unit of Clinical Neuroscience, University of Oulu, Oulu, Finland

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.

[11]Department of Neurosurgery and Brain Injury Centre, Turku University Hospital, Turku, Finland
[12]Department of Neurosurgery, St Olavs Hospital Universitetssykehuset i Trondheim, Trondheim, Trøndelag, Norway
[13]Department of Neurosurgery, Oslo University Hospital Ullevaal, Oslo, Norway
[14]Department of Neurosurgery, Rikshospitalet University Hospital, Oslo, Norway
[15]Department of Neurosurgery, Aalborg University Hospital, Aalborg, North Denmark Region, Denmark
[16]Department of Neurosurgery, Lund University Hospital, Lund, Sweden
[17]Department of Neurosurgery, Haukeland University Hospital, Bergen, Norway
[18]Department of Neurosurgery, University Hospital of North Norway, Tromso, Norway
[19]Department of Neurosurgery, Helsinki University Hospital and University of Helsinki, Helsinki, Finland
[20]Department of Neurosurgery in Linköping, and Department of Biomedical and Clinical Sciences, Linköping University, Linkoping, Östergötland, Sweden

Contributors Study initiation and design, protocol draft preparation: SoT, AL-C and MJ. Data collection: SoT, LA, JB, AC, AF, ANG, SAH, FLH, AH, CJ, O-PK, TK, AK, NMM, EEMM, RM, SM, HN-R, NO, LKP, JP, RR, JS, NS, SaT and LT. All authors reviewed and approved the final version of the protocol.

Funding As this is a retrospective chart review, limited funds are required. SoT has been partially funded by the Lundbeck Foundation (F-22218-19) and the Hjerne- og Nervekirurgisk Forskningspulje, Rigshospitalet (F23026-02, N497). No other specific funding has been received for this study.

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iDs
Sondre Tefre http://orcid.org/0000-0002-9516-4440
Alexander Lilja-Cyron http://orcid.org/0000-0003-2915-249X
Jiri Bartek http://orcid.org/0000-0002-2911-1914
Alba Corell http://orcid.org/0000-0002-6329-2392
Axel Forsse http://orcid.org/0000-0002-0325-0262
Andreas Nørgaard Glud http://orcid.org/0000-0003-3339-6120
Sami Abu Hamdeh http://orcid.org/0000-0001-6173-8357
Antti Huotarinen http://orcid.org/0000-0002-7212-5780
Conny Johansson http://orcid.org/0000-0001-8612-7173
Olli-Pekka Kämäräinen http://orcid.org/0000-0002-6111-3725
Tommi Korhonen http://orcid.org/0000-0002-5500-9200
Anna Kotkansalo http://orcid.org/0000-0002-3182-7786
Nadia Mauland Mansoor http://orcid.org/0000-0001-5668-3275
Rares Miscov http://orcid.org/0000-0003-0302-3497
Sune Munthe http://orcid.org/0000-0002-4793-9803
Henrietta Nittby-Redebrandt http://orcid.org/0000-0003-0140-8107
Jussi Posti http://orcid.org/0000-0002-5925-5193
Rahul Raj http://orcid.org/0000-0003-4243-9591
Jarno Satopää http://orcid.org/0000-0002-2674-0301
Sami Tetri http://orcid.org/0000-0002-1387-9136
Lovisa Tobieson http://orcid.org/0000-0003-2284-846X
Marianne Juhler http://orcid.org/0000-0003-2652-7495

REFERENCES

1 Reddy GK, Bollam P, Caldito G, *et al*. Ventriculoperitoneal shunt complications in hydrocephalus patients with intracranial tumors: an analysis of relevant risk factors. *J Neurooncol* 2011;103:333–42.
2 Merkler AE, Ch'ang J, Parker WE, *et al*. The rate of complications after ventriculoperitoneal shunt surgery. *World Neurosurg* 2017;98:654–8.
3 Reddy GK, Bollam P, Shi R, *et al*. Management of adult hydrocephalus with ventriculoperitoneal shunts: long-term single-institution experience. *Neurosurgery* 2011;69:774–81.
4 Grand W, Leonardo J, Chamczuk AJ, *et al*. Endoscopic third ventriculostomy in 250 adults with hydrocephalus: patient selection, outcomes, and complications. *Neurosurgery* 2016;78:109–19.
5 Bouras T, Sgouros S. Complications of endoscopic third ventriculostomy. *J Neurosurg* 2011;7:643–9.
6 Dusick JR, McArthur DL, Bergsneider M. Success and complication rates of endoscopic third ventriculostomy for adult hydrocephalus: a series of 108 patients. *Surg Neurol* 2008;69:5–15.
7 Kulkarni AV, Drake JM, Mallucci CL, *et al*. Endoscopic third ventriculostomy in the treatment of childhood hydrocephalus. *J Pediatr* 2009;155:254–9.
8 Foley RW, Ndoro S, Crimmins D, *et al*. Is the endoscopic third ventriculostomy success score an appropriate tool to inform clinical decision-making? *Br J Neurosurg* 2017;31:314–9.
9 Isaacs AM, Bezchlibnyk YB, Yong H, *et al*. Endoscopic third ventriculostomy for treatment of adult hydrocephalus: long-term follow-up of 163 patients. *Neurosurg Focus* 2016;41:E3.
10 Waqar M, Ellenbogen JR, Stovell MG, *et al*. Long-Term outcomes of endoscopic third ventriculostomy in adults. *World Neurosurg* 2016;94:386–93.
11 Dlouhy BJ, Capuano AW, Madhavan K, *et al*. Preoperative third ventricular bowing as a predictor of endoscopic third ventriculostomy success. *J Neurosurg Pediatr* 2012;9:182–90.
12 Kehler U, Regelsberger J, Gliemroth J, *et al*. Outcome prediction of third ventriculostomy: a proposed hydrocephalus grading system. *Minim Invasive Neurosurg* 2006;49:238–43.
13 Breimer GE, Sival DA, Brusse-Keizer MGJ, *et al*. An external validation of the ETVSS for both short-term and long-term predictive adequacy in 104 pediatric patients. *Childs Nerv Syst* 2013;29:1305–11.
14 Durnford AJ, Kirkham FJ, Mathad N, *et al*. Endoscopic third ventriculostomy in the treatment of childhood hydrocephalus: validation of a success score that predicts long-term outcome. *J Neurosurg Pediatr* 2011;8:489–93.
15 Hong S, Hirokawa D, Usami K, *et al*. The long-term outcomes of endoscopic third ventriculostomy in pediatric hydrocephalus, with an emphasis on future intellectual development and shunt dependency. *J Neurosurg Pediatr* 2018;23:104–8.
16 Dewan MC, Lim J, Shannon CN, *et al*. The durability of endoscopic third ventriculostomy and ventriculoperitoneal shunts in children with hydrocephalus following posterior fossa tumor resection: a systematic review and time-to-failure analysis. *J Neurosurg Pediatr* 2017;19:578–84.
17 Stovell MG, Zakaria R, Ellenbogen JR, *et al*. Long-Term follow-up of endoscopic third ventriculostomy performed in the pediatric population. *J Neurosurg* 2016;17:734–8.
18 Faggin R, Calderone M, Denaro L, *et al*. Long-Term operative failure of endoscopic third ventriculostomy in pediatric patients: the role of cine phase-contrast MR imaging. *Neurosurg Focus* 2011;30:E1.
19 Beuriat P-A, Puget S, Cinalli G, *et al*. Hydrocephalus treatment in children: long-term outcome in 975 consecutive patients. *J Neurosurg Pediatr* 2017;20:10–18.
20 Sacko O, Boetto S, Lauwers-Cances V, *et al*. Endoscopic third ventriculostomy: outcome analysis in 368 procedures. *J Neurosurg Pediatr* 2010;5:68–74.
21 Kadrian D, van Gelder J, Florida D, *et al*. Long-Term reliability of endoscopic third ventriculostomy. *Neurosurgery* 2005;56:1271–8.
22 Gangemi M, Mascari C, Maiuri F, *et al*. Long-Term outcome of endoscopic third ventriculostomy in obstructive hydrocephalus. *Minim Invasive Neurosurg* 2007;50:265–9.
23 Vulcu S, Eickele L, Cinalli G, *et al*. Long-Term results of endoscopic third ventriculostomy: an outcome analysis. *J Neurosurg* 2015;123:1456–62.
24 Vogel TW, Bahuleyan B, Robinson S, *et al*. The role of endoscopic third ventriculostomy in the treatment of hydrocephalus. *J Neurosurg* 2013;12:54–61.
25 Rahme R, Rahme RJ, Hourani R, *et al*. Endoscopic third ventriculostomy: the Lebanese experience. *Pediatr Neurosurg* 2009;45:361–7.
26 Gliemroth J, Käsbeck E, Kehler U. Ventriculocisternostomy versus ventriculoperitoneal shunt in the treatment of hydrocephalus: a

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.

retrospective, long-term observational study. *Clin Neurol Neurosurg* 2014;122:92–6.
27 Woodworth GF, See A, Bettegowda C, *et al*. Predictors of surgery-free outcome in adult endoscopic third ventriculostomy. *World Neurosurg* 2012;78:312–7.
28 Collins GS, Reitsma JB, Altman DG. Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): the TRIPOD statement. *BMJ* 2014;350.
29 Riley RD, Ensor J, Snell KIE, *et al*. Calculating the sample size required for developing a clinical prediction model. *BMJ* 2020;368:m441.
30 Nattino G, Finazzi S, Bertolini G. A new test and graphical tool to assess the goodness of fit of logistic regression models. *Stat Med* 2016;35:709–20.
31 Pedersen AB, Mikkelsen EM, Cronin-Fenton D, *et al*. Missing data and multiple imputation in clinical epidemiological research. *Clin Epidemiol* 2017;9:157–66.

BMJ Open: first published as 10.1136/bmjopen-2021-055570 on 31 January 2022. Downloaded from http://bmjopen.bmj.com/ on March 29, 2022 by guest. Protected by copyright.