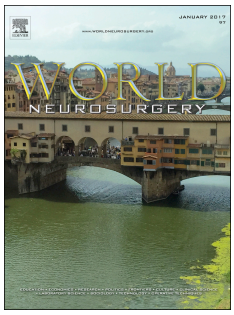

Early responses of neurosurgical practice to the COVID-19 pandemic: a rapid review.

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Early responses of neurosurgical practice to the COVID-19 pandemic: a rapid review.

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Abstract

Introduction

The novel coronavirus and subsequent pandemic have drastically transfigured healthcare delivery. Surgical specialties have seen severe alterations or reductions to practice, neurosurgery being one example where staff and resource reallocation has occurred to meet wider public health needs. This review summaries the published evidence detailing early experiences and changes to neurosurgical practice in response to the COVID-19 pandemic.

Materials and methods

A systematic review was conducted up until 21st April in accordance with PRISMA guidelines, searching Medline, EMBASE, Pubmed, Scopus, Cochrane Central and Web of Science Core Collection databases. Individual studies were qualitatively assessed to outline core themes detailing changes to practice. Iterative analysis allowed themes to be developed and applied to all studies included in the review.

Results

13 themes from 18 studies were identified, grouped into three overriding themes: logistics, human resources and clinical delivery. Studies originated from three of the most affected countries (USA, China and Italy), comprising of expert opinions, letters to the editor, editorials, case reports or perspective pieces. The commonest themes discussed include cancellation of elective operations, reduction in outpatient services and pandemic rotas.

Discussion

This review summaries the early responses of the neurosurgical community to the COVID-19 pandemic and presents a menu of interventions to be considered in future pandemic response, or in recurrent outbreaks of COVID-19. Whilst our review is limited by the low quality of evidence and rapid rate of change in our understanding of COVID-19, it provides a valuable summary of initial responses by the neurosurgical community to a global pandemic.

Introduction

The emergence of the novel coronavirus-19 (COVID-19)[1] and subsequent pandemic has seen the shape and delivery of healthcare rapidly change. A worldwide refocusing of health system priorities towards virus detection and response has triggered diversion of resources towards managing the growing burden of medical patients admitted to hospitals with respiratory compromise[2].

The COVID-19 pandemic has substantially impacted health systems globally. In developed health systems providing specialised services for patients with complex conditions, urgent reallocation of resources has been required to meet wider public health needs. A classic example is neurosurgical care provision, which often require significant resources, such as multidisciplinary teams and intensive care settings. Such gravid changes in health needs require significant adaptations to service delivery and surgical practice.

We conducted a systematic review to summarise the published evidence outlining the early experiences and initial changes to neurosurgical practice in response to the COVID-19 pandemic.

Materials and methods

A scoping review was performed to capture published evidence on early responses to the COVID-19 pandemic in neurosurgery, performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[3]. The search was conducted up until 21st April 2020. The initial search included all surgical specialties to improve the sensitivity of the search, with subsequent manual selection of neurosurgical papers from the search results performed by two authors (MN/LB). Databases searched included MEDLINE (via Ovid), EMBASE, PubMed, SCOPUS, Cochrane Central and Web of Science Core Collection. The keyword is detailed in supplementary appendix 1.

Each study was assessed by two independent reviewers (JH/GA). The origin, design and subspecialty of each study was noted. Studies were assessed for themes outlining interventions or changes to practice enacted by neurosurgical departments conducted in response to the pandemic. Interventions conducted in response to the pandemic were extracted iteratively from each article, with the final compilation agreed upon by the authorship. Each study was then re-analysed with the full compilation of interventions. Data were grouped to thematic axes; each axis represented an action or intervention or change to surgical practice.

We supplemented the search with policy statements and guidelines from international neurosurgical and surgical bodies providing guidance for service delivery during the pandemic.

Due to the heterogeneity in study design and reporting, quality assessment was performed via structured critical appraisal and synthesis of the data from three authors (JH/CB/MS). Results were accordingly incorporated in the discussion thematic axes.

Results

Scope of literature

We selected 18 studies[4–21] (Figure 1). Table 1* provides a summary of the origin, design and subspecialty of each study. The majority (N = 9, 50%) were published from the United States, jointly followed by China and Italy (N = 4, 22.2%) comprising of perspective pieces, editorials, expert opinions or letters to the editor. Therefore, a formal quality assessment was performed via critical appraisal of the included manuscripts. Half of the studies provided experiences from the general neurosurgery perspective, with others detailing subspecialty experiences and related recommendations, the most common being neuro-oncology (N = 4, 22.2%).

Themes

An array of 13 discrete thematic (intervention) axes were identified from critical synthesis of the literature (Table 2 †).

Isolation of suspected/confirmed COVID cases

10 studies described measures to isolate suspected or confirmed COVID patients[7,10–12,14–16,18,19,21], achieved most commonly through designated wards[7,10,11,14,19] and intensive care units to manage COVID patients[14,16,18]. Other studies described hospitals allocated to admit suspected COVID patients[12,21] or to manage non-COVID neurosurgical cases[15]. Isolation often began before admission in non-emergency cases and emergencies were treated as suspected COVID[14,21]. In some centres, confirmed COVID patients were separated from suspected COVID patients[10,11].

Intensive care unit (ICU) capacity

Eight studies outlined interventions to optimise ICU capacity[4,6,9,10,14,16,18,19] with most outlining a need to increase capacity[4,9,14,16,18]. Resources were reallocated from operating theatres[14] and previously designed neurological ICUs reallocated to manage COVID patients[16]. Expectation for paediatric resources to supplement the disproportionate disease burden in adults was also noted[4]. Postponement or cessation of elective operating, alongside post-operative recovery in alternative care settings was also initiated to preserve ICU capacity[9,18,19].

Hub centre allocation

Three studies all of Italian origin detailed a reorganisation of national neurosurgical networks to establish hub centres to deal with specific emergencies[13,14,17].

Pandemic rotas

Introducing pandemic rotas to restructure clinical teams has been proposed to reduce avoidable staff interaction, reducing viral exposure[7,9,19–21,11–18]. This was achieved by cohorting teams into separate, alternating groups[4,7,11–14,19] or encouraging non-essential workers, particularly in the administrative or research faculty, to work from home[15,18]. However, some studies discussed the importance of maintaining essential research facilities such as long-term experiments, employing dual clinical and research staff to continue research duties. This was underpinned in another through the importance of ongoing clinical trials in their later stages[9].

Redeployment of neurosurgical team

To maximise the capability of providers to manage the growing burden of medical admissions, neurosurgical staff were reallocated to other departments[13,14,16,17,20]. One hospital in Italy saw 75% of their team redistributed

to medical teams at one point[14], justified as a rationalization of resources[13]. This was mostly to support ward cover[13,14,16] but one study saw allocation of neurosurgeons to the emergency department[16]. In the same study, researchers refocused their efforts from neurosurgery to COVID-19[16].

Personal Protective Equipment Guidance

A number of studies acknowledged the global shortage of adequate PPE and thus the need to preserve them as much as possible[8–11,18,19,21]. Specific guidance on the level of PPE spanned from level 1 for suspected COVID patients which included surgical cap, surgical face mask, protective gown and gloves to level 3 for confirmed cases, which requires the addition of an N95 mask as well as a face shield and full-face piece respirator[10,21]. A particular concern on the rate of false negatives was the focus of two studies, urging staff to consider PPE especially in presumed COVID-negative cases[8,19].

Cancellation of elective surgery

Most studies discussed cancellation of elective surgeries as a priority[4,5,16–21,6,8,9,11–15]. This was due to the growing wider public health needs compared to elective surgical care[4,9,17,20]. Others highlighted the added risk to patients during the pandemic [6,19–21]. However, one study criticised the dichotomy of emergency and elective care in decision making, due to the anticipatory harms of delay in those with presently stable disease[4]. Two studies raised the higher risk of transmission to clinicians from surgery[8,11]. One study highlighted the future need for increased capacity following the pandemic to meet the back-log of delayed elective surgical cases[20].

Remodelling of outpatient services

Several alterations to outpatient care were detailed, with most studies describing a reduction in outpatient services[4,6,18,20,8,9,11,13–17]. Most studies only allowed urgent or emergency appointments[4,6,8,13,14,16–18], some with triaging or screening systems in place[9,11,18]. Burke et al. scaled provision of clinics depending on pandemic severity[15]. Reductions in services were often compensated with telemedicine alternatives[9,15,16,18,20]. Disinfections strategies for outpatient departments and patient education on PPE were also implemented[11], and changes to practice including administration of medications and use of certain procedures were curtailed[8]. However, closer outpatient monitoring of potentially aggressive low-grade gliomas was described as an alternative to standard surgical care[9].

Patient Education

The responsibility of physicians to educate their patients during this time has been highlighted by the literature. Mohile and colleagues detailed the need to underpin the importance of handwashing and social distancing measures during patient contact hours[6]. Also, emphasis was placed on communication of potential added vulnerability of certain neurosurgical patients[6,9].

Prohibiting Visitors

Several studies limited visitors[4,8,9,16,18], some prohibiting them entirely[4,9] whilst others allowed patients in paediatric and neonatal ICUs, as well as end-of-life care access to single family member per day[8,16,18]. Caridi described a redeployment of neurosurgical staff to liaison roles facilitating communication between patients and their families[16].

Operating Theatre Protocols

Reducing personnel within an operation theatre was a common strategy to reduce viral exposure[4,9,10,15,21], with specific reference to endonasal interventions[4,8,9,12]. Five studies suggested the use of negative pressure operating theatres to contain airborne pathogens and prevent cross-contamination[10,12,16,19,21]. Advocation of alternatives to surgery, such as radiosurgery or conservative observation through imaging were put forward[5,9]. Intraprocedural antifogging agent for eye protection[21] as well as the use of double gloves[10] were pointed out by two different studies to ensure accuracy and safety during interventions. Reduced drilling speed was proposed to minimise bone aerosol exposure[10] in addition to the renunciation of non-essential intraoperative neuromonitoring[9]. Unnecessary patient interaction was decreased by the use of dissolvable sutures and discharge planning to home rather than care settings[9,18].

Telemedicine

Telemedicine was discussed as a solution to reducing social contact to mitigate viral exposure[4,6,11,15,16,18,20]. Video conference sites such as Zoom, Skype and WeChat have all been put forward as a possible means of secure telehealth platforms for clinical visits and follow-up[4,11]. Criticisms included socioeconomic barriers posed by this switch, including language barriers, low technical literacy or little to no internet access[4,6].

Intubation Protocols

Strict intubation directives aimed to minimise clinician exposure to patient aerosols[4,9,11,19,20]. Prophylactic as opposed to intraprocedural intubation was favoured in most of the literature, with minimal staff present during the procedure[4,9,19,20]. Mandatory 30-minute delay between intubation and entrance of other operating room staff was trialled by two studies to reduce viral particulate exposure[4,20].

Discussion

This systematic review summarises the early published responses of neurosurgical departments to the COVID-19 pandemic. It provides a menu of interventions developed and implemented to reduce the spread and impact of the virus. These early experiences provide insights into the initial pandemic responses from healthcare systems globally, highlighting the common themes in neurosurgical responses during a pandemic. Identifying core themes provides insights to inform responses to future pandemics, or indeed, provide additional considerations in the short term for recurrent outbreaks of COVID-19.

Scope

A disproportionate number of studies were published from the USA, likely due to the combination of research capacity and high disease burden. Four studies provided experiences from China[10–12,21], one of which was a direct account from the central epidemic area where the infection is believed to have originated[1,10]. Similarly, four studies gave accounts from Italy[7,13,14,17] which sustained high infection rates early in the pandemic. This is a strength of this review as it summarises primary accounts from the worst affected nations and their experiences in pandemic response.

Interventions

The identified interventions in our review can be grouped into wider over-riding themes: logistics, human resources and clinical delivery.

Logistics

Isolating suspected and confirmed cases[7,10,11,14,19] required organisational restructuring of hospitals. This requires judicious infection control practices or division of the multidisciplinary team. With more specialised team members, such as the surgeon or anaesthetist, complete team division may be difficult in resource-limited settings, likely exacerbated by staff redeployment. Such cross-coverage may risk contamination of non-COVID wards. Others designated hospitals for COVID and non-COVID patients[12,21], which may be more effective in preventing contamination but requires a greater pool of resources. This was seen in Italy, where cooperation between centres nationally allowed establishment of hub centres to concentrate specialist resources[13,14,17]. Whilst our review does not compare their efficacy such approaches should be considered in the context of local resources.

Health systems internationally saw a need to redirect significant resources towards acute medical admissions, particularly ensuring critical care facilities for ventilatory support were made available for COVID patients[22]. Rationalisation and competition for resources meant providers had to minimize avoidable usage of these facilities, through postponing elective surgery. Capacity for COVID admissions was increased through means such as repurposing operating theatres[14] or reallocation of NICU beds[16]. Accounting for the wider public health need, it is incumbent on the neurosurgical team to be perceptive of surges in demand for these facilities in decision-making and patient communication[6] due to competition for high-level resources.

Human resources

Human resource management played an important role in the early responses in this review. The focal role of clinicians providing care means the consequences of healthcare workers becoming infected is great. Pandemic rotas optimise staffing whilst maintaining clinician reserves to replace those who develop symptoms, often through minimizing hospital staff attending work or division of teams. Yet, the long-term allocation of clinicians should account for both the pandemic response and the increasing burden of surgical patients who have had interventions cancelled or delayed[20]. Reduced staffing may also risk the quality of care provided by teams during the pandemic, with temporary staff or absence of routine team members impacting continuity of care.

Redeployment of neurosurgical teams to support COVID admissions mirrored the reduction in neurosurgical activity. The impact is likely disproportionately affecting junior staff, where more senior team members were required to manage emergency surgeries to reduce intraoperative time and therefore exposure[10]. Disruption to training programmes follows, with implications on the education and progression of trainees. Solutions have been found through online platforms in the continuation of grand rounds, educational conferences and teaching[10,16,18,20], supported by several webinar series and online lectures provided by international neurosurgical bodies, such as the World Federation of Neurosurgeons (WFNS).

Clinical delivery

Our review saw several significant changes to neurosurgical practice. Triaging of emergencies and urgent cases was seen throughout the literature, requiring centres to carefully select patients to delay intervention. Several

studies stated their criteria for such cases, outlining which presentations required emergent management. The American Association of Neurological Surgeons (AANS) and European Association of Neurosurgical Societies (EANS) produced triage guidelines modified from the ACS, who propose a 3 Tier system, whilst SBNS have produced more detailed sub-specialty guidance. However, Wellons and colleagues highlighted the simplification of pathologies to urgent and non-urgent, instead advocating for prioritization based upon anticipated harm of delays[4]. This provides an additional complexity where some disease may become inappropriate for intervention if delayed. Some studies described COVID-multidisciplinary team who were responsible for such decisions[9,10,13]. A consequence of triaging is the cancellation of elective surgeries. Whilst necessary to allow redirection of resources towards the wider medical needs, the morbidity and mortality of such delays is yet to be seen, alongside the future management of these patients when normal services resume.

Similarly, a large reduction in outpatient services to provide only essential clinics or treatments was described as another measure to reduce viral exposure. This saw a rapid reliance on telemedicine to provide various aspects of outpatient care. This unprecedented transfiguration of neurosurgical care may have lasting effects on outpatient care. Criticisms to these alternatives focus on the reliance on technology and the disproportionate socioeconomic impact on those who do not have access to such services, alongside the inferior human interface needed for sensitive or significant interactions between neurosurgeons and their patients[4,6]. Comparisons of these novel services, chiefly focusing on patient outcomes (both clinical and patient-reported outcome measures) to traditional outpatient services will allow true determination of their benefit. It does, however, demonstrate innovation in times of crisis.

Clinical practice was also modified in direct response to the pandemic. Cautions to providing particular surgeries, such as endonasal surgery, intubation protocols and advocation of alternative treatment strategies are examples of early changes to practice. These reflect concerns in the wider literature prompting strategies to minimize transmission intraoperatively[23]. These alterations serve to protect both patients and providers, meaning some actions are not solely patient-centred. Some studies attempted to avoid ICU admissions following certain surgeries, to preserve ICU beds for COVID patients[9,18,19]. Again, the impact of this is unclear. It may identify cases that can be managed in lower-intensity settings, improving efficiency of resource use. On the other hand, this may put patients who required critical care facilities at increased risk of complications or deterioration.

Limitations

This review aimed to characterise the scope of the early responses of the neurosurgical community to the COVID-19 pandemic. Thus, the steep learning curve means clinical practice is changing rapidly as more is learnt about the virus, impacting the sensitivity of the search. The quality of evidence in this systematic review was limited, formed of editorials, expert opinions and letters to the editor providing mostly institutional experiences in addressing the pandemic. This was unsurprising due to the proximity of the search to the pandemic outbreak. Further, the external validity of experiences discussed depend on local resource settings and thus may not be globally applicable. However, there is value in corroborating these experiences to inform the wider community on how institutions responded.

Conclusions

This review provides a summary of published evidence outlining the initial responses of the neurosurgical community to the COVID-19 pandemic. It provides a menu of pandemic response interventions conducted by countries initially with the highest disease burden of COVID-19 for consideration in response to future pandemics or, in the short term, further peaks in the COVID-19 pandemic. Compiling the early experiences offers healthcare providers insights into the modelling of neurosurgical units, internationally, to improve service provision and patient safety during a public health crisis.

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Conflicts of interest: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval: For this type of study formal consent is not required.

References

1. Alvarez-Pinzon AM, Wolf A, Delgado V, Valerio JE, González A, Alonso JR (2020) Letter to the Editor Regarding Effects of the COVID-19 Outbreak in Northern Italy: Perspectives from the Bergamo Neurosurgery Department, and the Role of Radiosurgery as a Minimally Invasive Procedure in the Pandemic Outbreak. World Neurosurg. doi: 10.1016/j.wneu.2020.04.209

2. Bernucci C, Brembilla C, Veiceschi P (2020) Effects of the COVID-19 Outbreak in Northern Italy: Perspectives from the Bergamo Neurosurgery Department. World Neurosurg 1–5

3. Burke JF, Chan AK, Mummaneni V, Chou D, Lobo EP, Berger MS, Theodosopoulos P V., Mummaneni P V. (2020) Letter: The Coronavirus Disease 2019 Global Pandemic: A Neurosurgical Treatment Algorithm. Neurosurgery 0(0):1–7

4. Caridi JM, Reynolds AS, Gilligan J, Bederson J, Dangayach NS (2020) Letter: News From the COVID-19 Front Lines: How Neurosurgeons Are Contributing. Neurosurgery. doi: 10.1093/neuros/nyaa205

5. Dobran M, Paracino R, Iacoangeli M (2020) Letter to the editor by Dobran Mauro, Paracino Riccardo, and Iacoangeli Maurizio regarding "Neurosurgery during the COVID-19 pandemic: update from Lombardy, northern Italy." Zoia C, Bongetta D, Veiceschi P, Cenzato M, Di Meco F, Locatelli D, Boeris D, Fon. Acta Neurochir (Wien). doi: 10.1007/s00701-020-04332-7

6. Eichberg DG, Shah AH, Luther EM, Menendez I, Jimenez A, Perez-Dickens M, O'Phelan KH, Ivan ME, Komotar RJ, Levi AD (2020) Letter: Academic Neurosurgery Department Response to COVID-19 Pandemic: The University of Miami/Jackson Memorial Hospital Model. Neurosurgery 0(0):1–3

7. Fraser JF, Arthur AS, Chen M, et al (2020) Society of NeuroInterventional Surgery recommendations for the care of emergent neurointerventional patients in the setting of covid-19. J Neurointerv Surg 1–3

8. Ghogawala Z, Kurpad S, Falavigna A, et al (2020) Editorial. COVID-19 and spinal surgery. J Neurosurg Spine 1–3

9. Hu YJ, Zhang J min, Chen Z ping (2020) Experiences of practicing surgical neuro-oncology during the COVID-19 pandemic. J Neurooncol. doi: 10.1007/s11060-020-03489-6

10. Kolias A, Tysome J, Donnelly N, et al (2020) A safe approach to surgery for pituitary and skull base lesions during the COVID-19 pandemic. 11–13

11. Koonin LM, Pillai S, Kahn EB, Moulia D, Patel A (2020) Strategies to Inform Allocation of Stockpiled Ventilators to Healthcare Facilities During a Pandemic. 18(2):69–74

12. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 6(7):e1000097

13. Mohile NA, Blakeley JO, Gatson NTN, et al (2020) Urgent considerations for the neuro-oncologic treatment of patients with gliomas during the COVID-19 pandemic. Neuro Oncol. doi: 10.1093/neuonc/noaa090

14. Panciani PP, Saraceno G, Zanin L, Renisi G, Signorini L, Fontanella MM (2020) Letter: COVID-19 Infection Affects Surgical Outcome of Chronic Subdural Hematoma. Neurosurgery 0(0):1–5

15. Patel ZM, Fernandez-Miranda J, Hwang PH, Nayak J V, Dodd R, Sajjadi H, Jackler RK (2020) Letter: Precautions for Endoscopic Transnasal Skull Base Surgery During the COVID-19 Pandemic. Neurosurgery 0(0):1–2

16. Ramakrishna R, Zadeh G, Sheehan JP, Aghi MK (2020) Inpatient and outpatient case prioritization for patients with neuro-oncologic disease amid the COVID-19 pandemic: general guidance for neuro-oncology practitioners from the AANS/CNS Tumor Section and Society for Neuro-Oncology. J Neurooncol. doi: 10.1007/s11060-020-03488-7

17. Tan Y tang, Wang J wen, Zhao K, Han L, Zhang H qiu, Niu H quan, Shu K, Lei T (2020) Preliminary Recommendations for Surgical Practice of Neurosurgery Department in the Central Epidemic Area of 2019 Coronavirus Infection. Curr Med Sci. doi: 10.1007/s11596-020-2173-5

18. Wang X, Wang M-J, Jiang X-B, Wang H-J, Zhao H-Y (2020) Letter: Strategies for Prevention and Control of 2019 Novel Coronavirus Infection Among Medical Staff. Neurosurgery. doi: 10.1093/neuros/nyaa117

19. Wellons JC, Grant G, Krieger MD, Ragheb J, Robinson S, Weprin B, Ojemann J (2020) Editorial. Early lessons in the management of COVID-19 for the pediatric neurosurgical community from the leadership of the American Society of Pediatric Neurosurgeons. J Neurosurg Pediatr 1–2

20. Wu F, Zhao S, Yu B, et al (2020) A new coronavirus associated with human respiratory disease in China. Nature 579(7798):265–269

21. Zhu W, Huang X, Zhao H, Jiang X (2020) A COVID-19 Patient Who Underwent Endonasal Endoscopic Pituitary Adenoma Resection: A Case Report. Neurosurgery 0(0):1–7

22. Zoia C, Bongetta D, Veiceschi P, Cenzato M, Di Meco F, Locatelli D, Boeris D, Fontanella MM (2020) Neurosurgery during the COVID-19 pandemic: update from Lombardy, northern Italy. Acta Neurochir (Wien). doi: 10.1007/s00701-020-04305-w

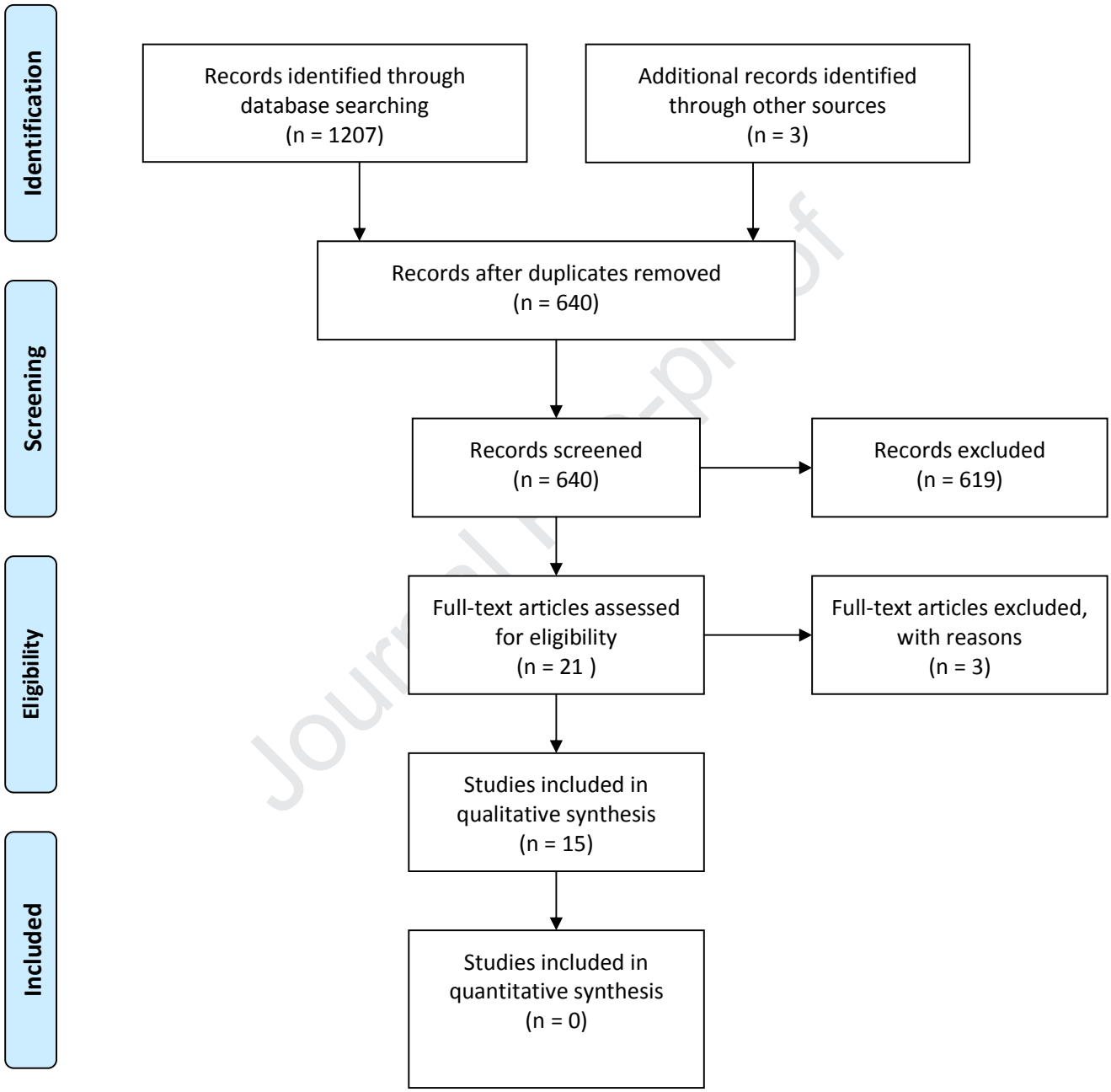
23. (2020) Global guidance for surgical care during the COVID-19 pandemic. Br J Surg. doi: 10.1002/bjs.11646

Study ID	Year	First Author	Country of origin	Study design
1	2020	Bernucci et al.[5]	Italy	Perspective
2	2020	Burke et al.[14]	United States	Letter to the editor
3	2020	Eichberg et al.[17]	United States	Letter to the editor
4	2020	Fraser et al.[18]	United States	Expert opinion
5	2020	Ghogawala et al.[19]	United States	Editorial
6	2020	Hu et al. [20]	China	Perspective
7	2020	Mohile et al.[21]	United States	Expert opinion
8	2020	Panciani et al.[6]	Italy	Letter to the editor
9	2020	Ramakrishna et al.[8]	United States	Expert opinion
10	2020	Tan et al.[9]	China	Perspective
11	2020	Wellons et al.[11]	United States	Expert opinion
12	2020	Zhu et al.[12]	China	Case report
3	2020	Zoia et al.[13]	Italy	Perspective
14	2020	Caridi et al.[15]	United States	Letter to the editor
15	2020	Patel et al. [7]	United States	Letter to the editor
16	2020	Alvarez-Pinzon et al.[4]	Spain	Letter to the editor
17	2020	Wang et al.[10]	China	Letter to the editor
18	2020	Dobran et al.[16]	Italy	Letter to the editor

Study ID	Author	ICU Capacity	Isolation of COVID cases	Staff deployment	Outpatient service reduction	Hub centre allocation	Elective case cancellation	Intubation protocols	PPE guidance	Telemedicine	OT Protocols	Prohibiting visitors	Pandemic rotas	Patient education
1	Bernucci et al.[5]	+	+	+	+	+	+	-	-	-	-	-	+	-
2	Burke et al.[14]	-	+	-	+	-	+	-	-	+	+	-	+	-
3	Eichberg et al.[17]	+	+	-	+	-	+	-	+	+	-	+	+	-
4	Fraser et al.[18]	+	+	-	-	-	+	+	+	-	-	-	+	-
5	Ghogawala et al.[19]	-	-	+	+	-	+	+	+	+	+	-	+	-
6	Hu et al. [20]	-	+	-	-	-	+	-	+	+	+	-	-	-
7	Mohile et al.[21]	+	-	-	+	-	+	+	+	+	-	-	+	+
8	Panciani et al.[6]	-	+	-	-	-	-	-	-	-	-	-	-	+
9	Ramakrishna et al.[8]	+	-	-	+	-	+	+	+	+	+	+	-	+
10	Tan et al.[9]	+	+	-	-	-	-	-	+	-	+	-	+	+
11	Wellons et al.[11]	+	-	-	+	-	+	+	+	+	+	+	+	-
12	Zhu et al.[12]	-	+	-	-	-	+	-	+	-	+	-	+	-
3	Zoia et al.[13]	-	-	+	+	+	+	-	-	-	+	-	+	-
14	Caridi et al.[15]	+	+	+	+	-	+	-	-	+	-	+	+	-
15	Patel et al. [7]	-	-	-	+	-	+	-	+	-	+	+	+	-
16	Alvarez-Pinzon et al.[4]	-	-	-	-	-	+	-	-	-	+	-	-	-
17	Wang et al.[10]	-	+	-	+	-	+	-	+	+	+	-	-	-
18	Dobran et al.[16]	-	-	+	+	+	+	-	-	-	-	-	+	-

Table 2 – Interventions (thematic axes) described by individual studies †

PRISMA 2009 Flow Diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Abbreviations:

AANS – American Association of Neurological Surgeons

COVID-19 – Corona Virus Disease 2019

EANS – European Academy of Neurological Surgeons

ICU – Intensive Care Unit

NICU – Neurosciences Intensive Care Unit

PPE – Personal Protective Equipment

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

SBNS – Society of British Neurological Surgeons

USA – United States of America

WFNS – World Federation of Neurosurgical Societies

Disclosure of interest statement:

On behalf of the authors, I confirm there are no disclosures of conflicts of interests pertinent to this manuscript.

Dr John Gerrard Hanrahan

Dear Dr Benzel,

This CRediT statement outlines the contributions of authors in our submission entitled “Early responses of neurosurgical practice to the COVID-19 pandemic: a rapid review”.

Conceptualization

Dr John Gerrard Hanrahan is the lead author, who conceived the idea alongside Mr Marios Nicolaides and Mr Louis Boyce.

Data curation

Mr Marios Nicolaides and Mr Louis Boyce designed the search strategy and completed the initial extraction to select out relevant neurosurgical articles.

Mr Gideon Adegboyega and Dr John Hanrahan completed the initial review, adding in additional articles from references and developing the thematic axes. These axes were reviewed by Dr Kendra Wong and Dr Sideris for refinement.

Analysis

Dr Burford additionally reviewed established guidelines to support the discussion. Dr Hanrahan, Dr Sideris and Dr Burford completed the critical quality assessment of all studies.

Supervision

Dr Sideris and Dr Hanrahan were senior authors for the study, coordinating the data collection and overall study direction.

Writing and editing

Dr Hanrahan drafted and edited the manuscript. Mr Gideon Adeboyega assisted in drafting of the results and discussion. Dr Michail Sideris and Dr Charlotte Burford reviewed and edited the manuscript. All authors contributed to the discussion points and final review of the manuscript prior to publication.

With kind regards,

On behalf of the authors.

Dr John Gerrard Hanrahan