Family-acquired photographs for the evaluation of pediatric head shape via telemedicine: an analysis of photograph quality

Mitch R. Paro, BA,1 William A. Lambert, BS,1 Nathan K. Leclair, BS,1 Arijit R. Chakraborty, MA,1 Sophia Angelo, BS,1 Benjamin Pesante, MS,1 Petronella Stoltz, DNP, APRN,2 Jonathan E. Martin, MD,2,3 Markus J. Bookland, MD,2,3 and David S. Hersh, MD2,3

1UConn School of Medicine, Farmington, Connecticut; 2Division of Neurosurgery, Connecticut Children’s, Hartford, Connecticut; and 3Department of Surgery, UConn School of Medicine, Farmington, Connecticut

OBJECTIVE Telemedicine can be an effective tool for the evaluation of the pediatric patient with a cranial deformity, but it increases the reliance of neurosurgical providers on data provided by patients and families. Family-acquired photographs, in particular, can be used to augment the evaluation of pediatric head shape abnormalities via telemedicine, but photographs of sufficient quality are necessary. Here, the authors systematically reviewed the quality and utility of family-acquired photographs for patients referred to their pediatric neurosurgery clinic for telemedicine-based head shape evaluations.

METHODS All telemedicine encounters that were completed for head shape abnormalities at the authors’ institution between May 2020 and December 2021 were retrospectively reviewed. Instructions were sent to families prior to each visit with examples of ideal photographs. Three orthogonal views of the patient’s head—frontal, lateral, and vertex—were requested. Data were collected regarding demographics, diagnosis, follow-up, and photograph quality. Quality variables included orthogonality of each requested view, appropriate distance, appropriate lighting, presence of distracting elements, and whether hair obscured the head shape.

RESULTS Overall, 565 patients had 892 visits during the study period. A total of 1846 photograph requests were made, and 3335 photographs were received for 829 visits. Of 2676 requested orthogonal views, 1875 (70%) were received. Of these, 1826 (97%) had adequate lighting, 1801 (96%) had appropriate distance, and 1826 (97%) had no distracting features. Hair did not obscure the head shape on the vertex view in 557 visits with orthogonal vertex views (82%). In-person follow-up was requested for further medical evaluation in 40 visits (5%).

CONCLUSIONS The family-acquired photographs in this series demonstrated high rates of adequate lighting and distance, without distracting features. Lack of orthogonality and obscuration of the head shape by hair, however, were more common issues. Family education prior to the visit may improve the quality of family-acquired photographs but requires an investment of time by medical staff. Efforts to further improve photographic quality will facilitate efforts to perform craniometric evaluations through telemedicine visits.

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KEYWORDS telemedicine; medical photography; pediatrics; plagiocephaly; craniosynostosis; craniometrics

Telemedicine has been previously used by neurosurgeons to facilitate the evaluation of neurotrauma patients,1–3 triage stroke patients,4 and care for those in underresourced areas.5–7 More recently, telemedicine has become widely adopted, driven by safety concerns and social distancing requirements as a result of the COVID-19 pandemic.8–13 Recent studies have found telemedicine to be effective14–17 and, in many cases, a satisfactory substitute for the in-person clinic visit.18–20 Preliminary evidence has supported the feasibility of a virtual craniofacial clinic and the diagnostic accuracy of head shape assessments via telemedicine.16 Similarly, our group has demonstrated the ability to screen for craniosynostosis in a telemedicine setting using image processing techniques and machine learning classification algorithms.21 This neonatal cranial deformity classification software uses orthogonal-view 2D images of the patient’s head to acquire craniometric measurements in a semiautomated fashion. Software such as this has the ability to augment the virtual assessment of cranial deformities with...
Methods

Patient Cohort

This study was approved by the institutional review board at Connecticut Children's. An automated report generated by the electronic medical record was used to identify all pediatric neurosurgical outpatient encounters between May 6, 2020, and December 27, 2021. Completed telemedicine encounters with one of the following diagnoses were retrospectively reviewed: plagiocephaly, craniosynostosis, congenital malformation of skull or facial bones, craniofacial dysostosis, and other acquired deformities of the head.

Clinical Protocol

During the study period, each patient’s legal guardian was emailed a request for photographs and a set of photograph instructions. Three orthogonal views of the patient’s head were requested: vertex, frontal, and lateral. The guardian was asked to 1) maintain a distance of 1–3 feet between the camera and patient, 2) keep the patient’s head in focus, and 3) wet the patient’s hair prior to taking the photograph in cases in which the hair might make it difficult to see the shape of the skull. Photographs were uploaded directly to the patient portal of the electronic medical record to maintain confidentiality. Reminders were sent via the patient portal to those who did not provide photographs prior to the scheduled visit. On receipt, photographs were evaluated by a nurse or medical assistant. If the photographs were deemed inadequate, the instructions were clarified, and additional photographs were requested.

Data Collection

Patient demographics and encounter characteristics were retrospectively collected. These variables included medical record number, patient name, date of birth, appointment date, appointment type (established or new), race, ethnicity, sex, language, primary insurance payer, primary encounter diagnosis, and status of the next encounter. Additional variables included the number of requests for photographs by the provider, the number of photographs received, and the quality of the photographs.

Assessment of Photograph Quality

All photographs were evaluated by two independent reviewers, and disagreements were mediated by a third independent reviewer. Variables corresponding to photograph quality included presence of an orthogonal photograph corresponding to each requested view (vertex, frontal, and lateral), appropriate distance, appropriate lighting, presence of distracting elements, presence of wet hair in the vertex view, and obscuration of the head shape by hair in the vertex view. Nonorthogonal views were excluded from analysis of the other variables. In cases in which families provided multiple examples of a given view, one best image was selected for analysis such that a maximum of three orthogonal images were reviewed for each encounter.

The orthogonality of the vertex view was determined based on the ability to identify the margins of the eurypterid, glabella, and opisthocranion, and the head shape was traced using these landmarks. The orthogonality of the frontal and lateral views was based on the symmetry of available landmarks (i.e., the position and relative visibility of the ears for the frontal view and the visibility of the contralateral face for the lateral view). The other variables (distance, lighting, distracting elements, and hair obscuration) were assigned a binary value of “acceptable” versus “not acceptable” based on the ability to reliably identify the outline of the head with respect to the above landmarks. To evaluate the efficacy of wetting the hair to improve head shape visualization, we stratified visits with respect to whether there was minimal hair or more than minimal hair in the vertex view, based on whether the scalp was visible for > 75% of the circumference of the equator.

Statistical Analysis

Descriptive statistics were performed using mean and standard deviation for continuous variables and frequency and percentage for categorical variables. Pearson’s chi-square test was used to compare categorical variables between groups; p < 0.05 was considered significant.

Results

Patient Characteristics

The demographics and primary diagnoses of the cohort are summarized in Table 1. Overall, 373 patients (66%) were male. Guardians of 363 patients (64%) identified the patient as White or Caucasian and 150 (27%) as other races, while race was unknown for 52 patients (9%). Guardians of 133 patients (24%) identified the patient as Hispanic or Latino ethnicity, and 16 (3%) self-identified a language preference other than English. Regarding insurance, 254 patients (45%) had private insurance, and 311 (55%) had Medicare/Medicaid. The primary diagnosis was craniosynostosis in 58 patients (10%) and positional deformity in the remaining 507 patients (90%).

Visits and Follow-Up

During the study period, the 565 patients described above had 892 telemedicine visits for evaluation of their head shape. The characteristics of these visits are described in Table 2. There were no subsequent follow-up
visits for 407 visits (46%), and 485 (54%) had at least one requested follow-up. A total of 40 follow-up visits (5%) were conducted in-person to further evaluate concerning findings where serious pathology could not be ruled out with photographs and telemedicine.

**Photographs Received**

Photographs were received from families for 829 visits (93%). For 231 (28%) of these visits, photographs were sent after only one request, and multiple reminders were required for 598 visits (72%) before the photographs were sent. A total of 1846 requests were sent (mean 2.1 ± 0.9 requests/visit). Forty-one visits (5%) required follow-up requests for additional photographs because of poor quality of the initial images. Ultimately, 3335 photographs were received for the 829 visits (mean 3.7 ± 1.8 photographs/visit). Overall, 698 visits (78%) visits included all three requested views (frontal, vertex, and lateral). A vertex view was received for 791 visits (89%), frontal view for 766 visits (86%), and lateral view for 778 visits (87%).

**FIG. 1.** Cranial landmarks used to determine orthogonality. **Upper:** Identification of the glabella, left and right euryon, and opisthocranion in an orthogonal vertex photograph allows accurate tracing of the head shape. **Lower:** Example of a vertex photograph with inability to identify the glabella and trace the equator of the head. This photograph was therefore determined to be nonorthogonal.

**FIG. 2.** Examples of different levels of hair coverage. **A:** Minimal hair coverage. Hair wetting would make no difference in visibility of the landmarks. **B:** More than minimal hair coverage (the scalp is only visible for the anterior portion of the equator of the head), but the hair does not obscure the ability to identify the necessary landmarks. **C:** Hair obscuring the head shape.
An assessment of the quality of the photographs was performed for each visit at which photographs were received (Table 3 and Fig. 3). Of 2676 requested orthogonal views (total visits × 3), 1875 orthogonal views were received (mean 2.3 ± 0.9 orthogonal views/visit with any photographs). Overall, 421 visits (51% of visits with any photographs) had three orthogonal views, 246 (30%) had two, 120 (14%) had one, and 42 (5%) had zero. The vertex view was orthogonal in 677 photographs (86% of the vertex views), the lateral view was orthogonal in 585 (75% of the lateral views), and the frontal view was orthogonal in 613 (80% of the frontal views).

Lighting, Distance, and Distracting Features
Of the orthogonal views, 1826 (97%) had appropriate lighting, 1801 (96%) were taken at an appropriate distance from the child’s head, and 1826 (97%) had no distracting features.

Hair Coverage
The vertex view was obscured by hair in 120 (18%) orthogonal vertex views. The hair was wet for 136 (20%) of the orthogonal vertex views with more than minimal hair (Fig. 4). Among these views, the hair did not obscure the head shape in 104 (76%) photographs. Among orthogonal vertex views with more than minimal hair that was dry, the hair did not obscure the head shape in only 112 (56%) photographs (p = 0.0002).

General Observations
Many families sent images of posteroanterior views of patients’ heads, although they were never requested. Many families also sent photographs only of incisions for postoperative visits following craniosynostosis surgery, omitting requested views for the head shape evaluation. Families used various strategies to obtain high-quality photographs, including laying the child down on a flat surface, placing them in a secured seat, or having one adult hold the child while another adult took the picture.

Discussion
As telemedicine becomes increasingly widespread throughout neurosurgery, efforts to optimize the telemedicine experience have taken on new significance. Family-acquired photographs, in particular, can be used to augment the evaluation of pediatric head shape abnormalities via telemedicine, but photographs of sufficient quality are necessary. In the current series, we found that family-acquired photographs were obtained for almost all (93%) of the virtual visits during the study period. Furthermore, only 5% of visits required in-person follow-up and/or imaging when the telemedicine visit was considered insufficient. Further improving the quality of family-acquired photographs will increase the data available to the provider, facilitate computer-based image analysis techniques, and enable the provider to screen for craniosynostosis prior to the visit itself.

Lack of orthogonality was one of the most common issues noted during our analysis of photograph quality. Indeed, optimal photographs can be difficult to obtain, both for neonates without head control as well as for older

| TABLE 1. Patient characteristics | Value |
|----------------------------------|-------|
| No. of patients                  | 565   |
| Mean age ± SD at 1st encounter, mos | 8.7 ± 10.5 |
| Sex, n (%)                       |       |
| Male                             | 373 (66) |
| Female                           | 192 (34) |
| Race, n (%)                      |       |
| White or Caucasian               | 363 (64) |
| Other                            | 150 (27) |
| Unknown                          | 52 (9) |
| Ethnicity, n (%)                 |       |
| Not Hispanic or Latino           | 400 (71) |
| Hispanic or Latino               | 133 (24) |
| Unknown                          | 32 (6) |
| Preferred language, n (%)        |       |
| English                          | 546 (97) |
| Other                            | 16 (3) |
| Unknown                          | 3 (0) |
| Primary payer, n (%)             |       |
| Private                          | 254 (45) |
| Medicare/Medicaid                | 311 (55) |
| Primary diagnosis at 1st encounter, n (%) |       |
| Craniosynostosis                 | 58 (10) |
| Positional deformity/other       | 507 (90) |

| TABLE 2. Visit characteristics | Value |
|---------------------------------|-------|
| Telemedicine visits             |       |
| Total                           | 892   |
| Mean no. per patient ± SD       | 1.6 ± 0.9 |
| Visit type, n (%)               |       |
| Established patient             | 536 (60) |
| New patient                     | 329 (37) |
| Postop patient                  | 27 (3) |
| Requests sent for photos        |       |
| Total                           | 1846  |
| Mean no. per visit ± SD         | 2.1 ± 0.9 |
| Photos received                 |       |
| Total                           | 3335  |
| Mean no. per visit ± SD         | 3.7 ± 1.8 |
| Visits w/ any photos received, n (% total visits) | 829 (93) |
| Follow-up, n (% total visits)   |       |
| Visits w/ follow-up             | 485 (54) |
| In-person follow-up requested for closer evaluation | 40 (5) |
infants and toddlers who are active and mobile. We noticed several trends. When frontal and lateral photographs were not orthogonal, they were frequently taken from a high vantage point (with the camera above the patient’s head and aiming downward), and nonorthogonal images tended to favor the photographer’s right hand for all views. Many nonorthogonal photographs deviated from a true orthogonal by only a few degrees, while other deviations were more significant. The lateral view was the most challenging, and only 75% of attempted lateral views were orthogonal. However, given that none of our craniometric measurements incorporate anatomical landmarks on the lateral view, this did not significantly affect the overall accuracy of the telemedicine visit.

Hair coverage was another common issue and obscured the outline of the skull in 18% of the orthogonal vertex views we obtained. As expected, hair coverage was more significant in older patients. However, we have found that wetting the patient’s hair improves visualization of the outline of the head, thereby increasing the reliability of 2D image-based craniometric measurements. As a result, a request to wet the hair was included in the pre-visit instructions sent to each patient’s legal guardian. Of the patients with more than minimal hair coverage in the vertex view, photographs with wet hair provided a clear visualization of the head shape more often than photographs without wet hair (76% vs 56%, p = 0.0002), suggesting that this is an effective strategy for improving photograph quality.

Families used various additional strategies to improve photograph quality. Regarding patient positioning, we observed that the two-adult approach—with one adult holding the patient and the other taking the photograph—tended to

| TABLE 3. Photograph quality |
|----------------------------|
| **Value**                  |
| Views received, n (% total visits) | 791 (89) |
| Visits w/ vertex view received | 766 (86) |
| Visits w/ lateral view received | 778 (87) |
| Visits w/ 3/3 views received | 698 (78) |
| Orthogonal views           |
| Vertex, n (% vertex views received) | 677 (86) |
| Frontal, n (% frontal views received) | 613 (80) |
| Lateral, n (% lateral views received) | 585 (75) |
| Adequate lighting, n (% orthogonal photos) | 1826 (97) |
| Appropriate distance, n (% orthogonal photos) | 1801 (96) |
| No distracting features, n (% orthogonal photos) | 1826 (97) |
| Hair coverage              |
| Minimal hair, n (% orthogonal vertex views) | 341 (50) |
| Mean age ± SD, mos | 6.6 ± 3.3 |
| Wet hair, n (% orthogonal vertex views) | 136 (20) |
| Hair did not obscure head shape, n (% photos w/ wet hair) | 104 (76) |
| Mean age ± SD, mos | 9.7 ± 8.7 |
| Dry hair (% orthogonal vertex views) | 200 (30) |
| Hair did not obscure head shape, n (% photos w/ dry hair) | 112 (56) |
| Mean age ± SD, mos | 11.3 ± 13.9 |

**FIG. 3.** Assessment of photograph quality. Examples of high-quality, orthogonal, top-down views, and examples of top-down views that were not orthogonal, had inappropriate lighting, were taken at an inappropriate distance, had distracting elements, and included hair that obscured the head shape.
reduce subject motion artifact and allowed for improved positioning of the patient’s head. Seating the child in a fixed position (such as in a highchair) had a similar effect. In contrast, laying the patient flat on a soft surface, such as a bed, often led to poor lighting of the posterior head and/or obscuration of the posterior head by distracting elements. Sitting the patient in the lap of the adult taking the picture also tended to produce poor lighting and reduce orthogonality. Additionally, the portrait mode setting, available on some smartphone cameras, increases the contrast between the object of focus and the environment and was used to good effect by some families in our series.

To our knowledge, this is the first reported analysis of family-acquired photographs obtained for the evaluation of pediatric head shape, although other studies have reported the utility of medical photographs within other domains of neurosurgery. Pirris et al., for example, documented one of the earliest series of patient-acquired photographs in neurosurgery, demonstrating the practicality of performing wound evaluations via telemedicine. Medical photography, particularly when acquired by the patient or family, has the potential to substantially expand the capabilities of the telemedicine evaluation. However, there are limitations that must be noted. Although telemedicine visits eliminate travel time for patients and families, there is a tradeoff in the time investment required on the part of medical staff, who must keep track of whether photographs have been provided, send reminders, and check the quality of the photographs prior to the visit. Additionally, although almost all families now have access to a smartphone with a camera, not all can navigate the technicalities of completing a telemedicine visit. We have previously demonstrated that demographic variables, including primary language and insurance status, are significant predictors of telemedicine utilization, and similar barriers to access may apply to families attempting to provide medical photographs.

Best Practices for Obtaining Family-Acquired Photographs

1) Clear, standardized instructions should be sent prior to the visit. Visual examples of optimal photographs should be included.

2) Instructions should be available in multiple languages.

3) The family should be instructed to wet the patient’s hair prior to taking the photographs.

4) The “portrait mode” setting on a smartphone camera can be considered to increase the contrast between the object of interest and the background. This allows the outline of the head to be sharply defined and may help minimize distracting elements.

5) When feasible, two adults should be involved in taking the photograph—one to serve as the photographer, and the other to hold the patient in a specific orientation.

6) A standardized, automated system of requesting photographs, providing instructions, sending reminders when photographs have not been received, and receiving and cataloging photographs should be utilized when available, to minimize the burden on office staff. However, a nurse or medical assistant may review the photographs prior to the visit to provide additional guidance and solicit higher-quality views when necessary.

7) Photographs should be uploaded to the electronic medical record through secure patient portals to maintain confidentiality.

Study Limitations

There are several limitations of this study, including its retrospective design. In particular, each variable that was used to assess photograph quality was qualitative in nature. However, any inherent subjectivity was mitigated by having two (and in cases of disagreement, three) reviewers evaluate each photograph. Ultimately, the key determinant of acceptability mirrored that which is used in our clinical practice—the ability to identify cranial landmarks and trace the outline of the head in order to calculate cranio-metrics.

Conclusions

Although the use of telemedicine by neurosurgeons rapidly expanded because of the COVID-19 pandemic, it is likely that telemedicine will persist as an attractive option for outpatient encounters even as the pandemic subsides. In addition to its convenience, telemedicine holds promise as a means to decrease costs and improve access to medical care. Electronically transmitted patient- or family-acquired medical photographs are a natural complement to the telemedicine encounter, particularly with the increasing sophistication of smartphone technology as well as image analysis via artificial intelligence and machine learning algorithms. However, the quality of these images can be widely variable. This analysis of our preliminary experience with family-acquired medical images utilized in our outpatient head shape clinic may provide insight into potential strategies to obtain high-quality images. Similar analyses in other neurosurgical subspecialties may continue to improve the reliability and efficiency of the telemedicine evaluation to optimize patient care.

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Author Contributions
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Supplemental Information
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Correspondence
David S. Hersh: Connecticut Children’s, Hartford, CT. dhersh@connecticutchildrens.org.