Use of Big Data and ML to Estimate Hospitalization Costs for Cleft Lip and Palate Treatment

2025 Research Aid Awards (RAA)

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FollowUp Form

Award Information

In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:

- *Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
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Title of Project:*

Use of Big Data and ML to Estimate Hospitalization Costs for Cleft Lip and Palate Treatment

Award Type

Research Aid Award (RAA)

Period of AAOF Support

July 1, 2025 through June 30, 2026

Institution

The Board of Trustees of the University of Illinois

Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s)

Veerasathpurush Allareddy (Project Mentor), Min Kyeong Lee (Co-mentor), Maysaa Oubaidin (Co-Investigator), Soumya Padala (Co-Investigator)

Amount of Funding
$6,000.00

Summary/Abstract*
(Referring to your original abstract, summarize the findings of your project)

Orofacial clefts are a public health concern worldwide, with 4.62 million people living with the defect and affecting 1.42 in 1000 live births in 2019. Patients with cleft lip and palate undergo multiple surgical interventions along with the continuum of cleft lip and palate care. The objective of this study is to provide nationally representative estimates of hospitalization costs associated with surgical interventions in those with cleft lip and palate and to identify high risk cohorts that are likely to have poor outcomes and increased utilization of hospital resources. Data from the National Inpatient Sample for years 2019 to 2022 will be used. Machine Learning Artificial Neural Network Models will be used to identify patient and hospital/provider level factors associated with costs of surgical interventions. The predictive machine learning models we will develop will enable patient risk stratification and serve as an indispensable tool for the clinicians and policy makers. Healthcare providers can proactively identify high risk cohorts who are likely to experience poor outcomes and implement preemptive interventions.

Respond to the following questions:

Detailed results and inferences:*
If the work has been published, please attach a pdf of manuscript below by clicking "Upload a file".
OR
Use the text box below to describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should also be attached by clicking "Upload a file".

Kanwal et al. Sem Orthodon 2025.pdf

Were the original, specific aims of the proposal realized?*
We were able to provide epidemiologic estimates of hospitalization outcomes in patients diagnosed with a primary or secondary diagnosis of CLP .

Were the results published?*
Yes

Have the results of this proposal been presented?*
Yes

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*

The funding from AAOF has helped me gain recognition in my professional journey. I was invited to speak at the Graber symposium in Aug 2025. My work was also awarded the best poster at the UIC College of Dentistry, Clinic and Research Day in March 2026 . This funding has helped me collaborate on more topics relating to the epidemiologic studies on CLP. This will significantly enhance my CV and help me secure an academic position upon graduation.

Accounting: Were there any leftover funds?*

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Bushra Kanwal BDS MDS MOrth RCSEd FOrth RCSEd, Michael D. HanDDS MD, Gloria Ahn DDS, Sofie Vogel BS, Maysaa Oubaidin DDS MS, Min Kyeong Lee DMD DMSc, Sankeerth Rampa MBA MPH PhD, Veerasathpurush AllareddyBDS MBA MHA PhD MMSc. Published in Seminar in Orthodontics and presented at Graber's symposium in Aug 2025 and won first place in poster presentation at the UIC Clinic and Research Day in March 2026.

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Internal Review

Reviewer comments

I have reviewed the final report and approve it as is. I congratulate the authors on their work and publication.

Reviewer Status*

Approved

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Epidemiological estimates of hospitalization outcomes in cleft lip and/or palate

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ABSTRACT

Objective: To provide nationally representative estimates of hospitalizations associated with cleft lip and/or palate (CLP).
Materials and methods: This is a retrospective analysis of the Nationwide Inpatient Sample for 2020 to 2022. All hospitalization with either a primary or secondary diagnosis of CLP were selected. Disposition following hospitalization was the primary outcome. Simple descriptive statistics were used to summarize the data.
Results: During the study period, a total of 37,895 hospitalizations had a diagnosis of CLP. This included 8615 hospitalizations with a primary diagnosis of CLP (reason for hospitalization) and 29,280 hospitalizations with only a secondary diagnosis of CLP (CLP present as a comorbid condition). Overall, whites and males comprised of majority of hospitalizations. Most hospitalizations occurred in urban teaching hospitals. Overall, across all types of clefts (Cleft Palate Only, Cleft Lip Only, and Cleft Palate with Cleft Lip), hospitalizations with a secondary diagnosis of any cleft had poorer outcomes in terms of higher mortality, longer length of stay in hospital, and higher hospital charges when compared to hospitalizations with a primary diagnosis of any cleft.
Conclusions: Our study provides epidemiological estimates of hospitalization outcomes of CLP. These findings can be used to help guide clinical and policy decisions, especially with stage-appropriate resource allocation.

Introduction

Cleft lip and/or palate (CLP) is among the most common congenital craniofacial anomalies worldwide.[1,2] The etiology of CLP is multi factorial and involves genetic and environmental components.[2] The care of these infants typically requires coordinated, long-term multidisciplinary care beginning in infancy and often extending into adulthood.[3] These individuals experience a wide range of health services from an early age with repeated admission to hospital, mainly for surgical procedures to correct the structural defects, a necessary feature of their care pathway.[4]

In part due to the associated anomalies, infants born with congenital abnormalities such as CLP are subject to greater morbidity and mortality compared with unaffected births.[5] During embryonic development, cleft palate arises from diverse morphogenic disruptions concurrently affecting other organ systems. Previous studies[6] have reported that the incidence of associated congenital anomalies ranges from 4.3 % to 63.4 %, most commonly involving cardiac, musculoskeletal, and central nervous system defects. The systemic conditions and the multiple exposure to surgery and anesthesia thereby increase the risk of intra operative and postoperative complications. For example, congenital pulmonary disorders (CPDs) have been described in children with CLP, predisposing them to difficult airway management and long-term respiratory morbidity.[7]

The causal mechanism underlying CLP and their associated co-morbidities are not clearly understood and there is a limited understanding of the patterns of health service utilization by this population. Studies in the literature have investigated the use of hospital services for children with CLP. Increased admissions and length of stay in hospital, accompanied by higher hospitalization costs have been described for children with CLP compared to children without CLP,[8,9] but these studies have focused particularly on admissions in the first one or two years of life. There are no studies that describe in detail, all admissions until adulthood.

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Given their role as Co-Guest Editors, Min Kyeong Lee and Veerasathpurush Allareddy, had no involvement in the peer review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to another journal editor.

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The aim of our study is to present nationally representative epidemiologic estimates of hospitalization outcomes in those with Cleft Lip and Palate. The characteristics of hospitalizations, the comorbid burden, and disposition status following hospitalization are presented by types of cleft.

Materials and methods

The Nationwide Inpatient Sample (NIS) for the years 2020 to 2022 was used for the present study. The NIS was developed by the Agency for Health Care Research and Quality (AHRQ) as part of the Healthcare Cost and Utilization Project (HCUP).[10] A data user agreement from HCUP-AHRQ was completed by all authors. The study was granted Human Subjects Institutional Review Board Exempt Status as this was secondary data analysis of an already existing database.

The NIS is a 20 % stratified sample of all hospitalizations occurring in the United States in a given year.[10] The NIS is the largest all-payer hospital discharge dataset and contains information on over 500 different variables at the individual discharge and hospital level. Each discharge record in this database refers to an individual hospitalization as opposed to an individual patient and is the unit of analysis in the present study. The NIS database has been validated and used for examining nationally representative estimates of hospitalization outcomes. Extensive documentation of the NIS database, file specifications, analytical programming codes to obtain the data, validation of datasets, quality control procedures and coding practices are available at https://hcup-us.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp.10

For the present study, all hospitalization with either a primary or secondary diagnosis of CLP were selected. There are 40 diagnostic fields (for ICD-10-CM codes) available in the NIS database. The primary diagnosis field refers to the primary reason for hospitalization and the secondary diagnoses fields indicate presence of a co-morbid condition, other diagnostic conditions identified or already present in a patient, or occurrence of an event during the hospitalization. We used ICD-10-CM diagnosis codes for identifying hospitalizations with CLP (see Table 1 for list of codes used) either with a primary diagnosis of CLP or as a secondary diagnosis. The below list of ICD-10 CM codes that were used to identify hospitalizations with CLP:

- Cleft hard palate (Q35.1)
- Cleft soft palate (Q35.3)
- Cleft hard palate with soft palate (Q35.5)
- Cleft uvula (Q35.7)
- Cleft palate, unspecified (Q35.9)
- Cleft lip, bilateral (Q36.0)
- Cleft lip, median (Q36.1)
- Cleft lip, unilateral (Q36.9)
- Cleft hard palate with bilateral cleft lip (Q37.0)
- Cleft hard palate with unilateral cleft lip (Q37.1)
- Cleft soft palate with bilateral cleft lip (Q37.2)
- Cleft soft palate with unilateral cleft lip (Q37.3)
- Cleft hard and soft palate with bilateral cleft lip (Q37.4)
- Cleft hard and soft palate with unilateral cleft lip (Q37.5)
- Unspecified cleft palate with bilateral cleft lip (Q37.8)
- Unspecified cleft palate with unilateral cleft lip (Q37.9)

Simple descriptive statistics were used to examine the demographic characteristics, presence of co-morbid conditions and disposition status following hospitalization. We stratified and presented the hospitalization characteristics and outcomes by type of cleft (Cleft Palate Only, Cleft Lip Only, and Cleft Palate with Cleft Lip). All estimates presented in this article were projected to national levels using the discharge weight variable and the NIS hospital stratum variable. For each hospitalization of record (unit of analysis), a discharge weight variable is assigned in the NIS database. The discharge weight and the stratum to which the hospital belongs were used as the "cluster" and "weight" respectively in the SAS program to project all estimates to nationally representative levels. This is the method recommended by NIS for computing nationally representative estimates of hospitalizations and associated outcomes.[10] Hospitalization charges were adjusted to year 2022 $ value using the Bureau of Labor Statistics Medical Care inflation calculator.[11] Descriptive analyses were conducted using SAS Version 9.4 software (SAS Institute, Cary, NC).

Results

During the study period (years 2020 to 2022), a total of 37,895 hospitalizations had a diagnosis of CLP. This included 8615 hospitalizations with a primary diagnosis of CLP (reason for hospitalization) and 29,280 hospitalizations with a secondary diagnosis of CLP (CLP present as a comorbid condition). The number of hospitalizations by cleft types (Cleft Palate Only, Cleft Lip Only and Cleft Palate with Cleft Lip) are presented in Table 1. There were 17,355 hospitalizations with a diagnosis of Cleft Palate Only, 4690 with Cleft Lip Only, and 15,985 with Cleft Palate with Cleft Lip. Amongst these three groups, 135 hospitalizations had more than one type of Cleft mentioned in the discharge record.

The characteristics of hospitalizations with different types of clefts by primary diagnosis (reason for hospitalization) and secondary diagnosis (present as a comorbid condition) are presented in Table 2. Overall, the

Table 1
Types of clefts amongst hospitalizations.

Type of Cleft (ICD-10 CM Code)		Hospitalizations with Primary Diagnosis N = 8615*	Hospitalizations with Secondary Diagnosis N = 29,280*
Cleft Palate Only (Q35)	Cleft hard palate (Q35.1)	215 (2.5 %)	775 (2.6 %)
	Cleft soft palate (Q35.3)	740 (8.6 %)	3070 (10.5 %)
	Cleft hard palate with soft palate (Q35.5)	980 (11.4 %)	965 (3.3 %)
	Cleft uvula (Q35.7)	65 (0.7 %)	1130 (3.9 %)
	Cleft palate, unspecified (Q35.9)	1130 (13.1 %)	8620 (29.4 %)
Cleft Lip Only (Q36)	Cleft lip, bilateral (Q36.0)	110 (1.3 %)	250 (0.8 %)
	Cleft lip, median (Q36.1)	DS	50 (0.2 %)
	Cleft lip, unilateral (Q36.9)	630 (7.3 %)	3655 (12.5 %)
Cleft Palate with Cleft Lip (Q37)	Cleft hard palate with bilateral cleft lip (Q37.0)	115 (1.3 %)	125 (0.4 %)
	Cleft hard palate with unilateral cleft lip (Q37.1)	215 (2.5 %)	390 (1.3 %)
	Cleft soft palate with bilateral cleft lip (Q37.2)	45 (0.5 %)	65 (0.2 %)
	Cleft soft palate with unilateral cleft lip (Q37.3)	165 (1.9 %)	305 (1 %)
	Cleft hard and soft palate with bilateral cleft lip (Q37.4)	625 (7.2 %)	645 (2.2 %)
	Cleft hard and soft palate with unilateral cleft lip (Q37.5)	1000 (11.6 %)	1105 (3.8 %)
	Unspecified cleft palate with bilateral cleft lip (Q37.8)	945 (11 %)	2430 (8.3 %)
	Unspecified cleft palate with unilateral cleft lip (Q37.9)	1780 (20.7 %)	6180 (21.1 %)

* **Note**: Sum of the individual cell counts (different types of clefts) is more than the global total since some hospitalizations had more than one type of cleft mentionedS
DS – Discharge information suppressed since individual cell count is ≤10 (per HCUP-AHRQ data user agreement).

Table 2
Hospitalizations with cleft lip and/or palate – descriptive characteristics.

Type of Clefts		Cleft Palate Only $N = 17,355$		Cleft Lip Only $N = 4690$		Cleft Palate with Cleft Lip $N = 15,985$	
Primary or Secondary Diagnosis of Cleft Lip and/or Palate		Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis
Characteristic	Response	$N = 3045$	$N = 14,310$	$N = 740$	$N = 3950$	$N = 4860$	$N = 11,125$
Year of Hospitalization	2020	1090 (35.8 %)	4485 (31.3 %)	255 (34.5 %)	1310 (33.2 %)	1665 (34.3 %)	3550 (31.9 %)
	2021	990 (32.5 %)	4850 (33.9 %)	250 (33.8 %)	1465 (37.1 %)	1605 (33 %)	3755 (33.8 %)
	2022	965 (31.7 %)	4975 (34.8 %)	235 (31.8 %)	1175 (29.7 %)	1590 (32.7 %)	3820 (34.3 %)
Sex	Data available for $N =$	3045	14,310	740	3950	4860	11,115
	Male	1380 (45.3 %)	6550 (45.8 %)	465 (62.8 %)	2300 (58.2 %)	2835 (58.3 %)	6295 (56.6 %)
	Female	1665 (54.7 %)	7760 (54.2 %)	275 (37.2 %)	1650 (41.8 %)	2025 (41.7 %)	4820 (43.4 %)
Race/ethnicity of patient	Data available for $N =$	2835	13,175	710	3540	4565	10,260
	White	1495 (52.7 %)	7360 (55.9 %)	325 (45.8 %)	2095 (59.2 %)	2020 (44.2 %)	5225 (50.9 %)
	Black	235 (8.3 %)	1400 (10.6 %)	40 (5.6 %)	330 (9.3 %)	365 (8 %)	1075 (10.5 %)
	Hispanic	635 (22.4 %)	2675 (20.3 %)	200 (28.2 %)	615 (17.4 %)	1410 (30.9 %)	2495 (24.3 %)
	Asian or Pacific Islander	220 (7.8 %)	665 (5 %)	55 (7.7 %)	170 (4.8 %)	385 (8.4 %)	545 (5.3 %)
	Native American	30 (1.1 %)	190 (1.4 %)	DS	60 (1.7 %)	85 (1.9 %)	230 (2.2 %)
	Other	220 (7.8 %)	885 (6.7 %)	85 (12 %)	270 (7.6 %)	230 (6.6 %)	690 (6.7 %)
Hospital/Geographic Region	Data available for $N =$	3045	14,310	740	3950	4860	11,125
	Northeast	600 (19.7 %)	2315 (16.2 %)	115 (15.5 %)	560 (14.2 %)	775 (15.9 %)	1310 (11.8 %)
	Midwest	580 (19 %)	3155 (22 %)	80 (10.8 %)	955 (24.2 %)	1235 (25.4 %)	2450 (22 %)
	South	995 (32.7 %)	5360 (37.4 %)	220 (29.7 %)	1465 (37.1 %)	1255 (25.8 %)	4520 (40.6 %)
	West	870 (28.6 %)	3480 (24.3 %)	325 (43.9 %)	970 (24.6 %)	1595 (32.8 %)	2845 (25.6 %)
Type of Admission	Data available for $N =$	3035	14,255	740	3950	4850	11,080
	Non-elective Admission (Emergency/Urgent)	400 (13.2 %)	11,780 (82.6 %)	65 (8.8 %)	3680 (93.2 %)	480 (9.9 %)	9290 (83.8 %)
	Elective Admission	2635 (86.8 %)	2475 (17.4 %)	675 (91.2 %)	270 (6.8 %)	4370 (90 %)	1790 (16.2 %)
Hospital Location/ Teaching Status	Data available for $N =$	3045	14,310	740	3950	4860	11,125
	Rural Hospital	20 (0.7 %)	620 (4.3 %)	DS	290 (7.3 %)	20 (0.4 %)	495 (4.4 %)
	Urban Nonteaching	15 (0.5 %)	1155 (8.1 %)	DS	520 (13.2 %)	30 (0.6 %)	910 (8.2 %)
	Urban Teaching	3010 (98.9 %)	12,535 (87.6 %)	735 (99.3 %)	3140 (79.5 %)	4810 (99 %)	9720 (87.4 %)
Insurance Status	Data available for $N =$	3040	14,305	740	3940	4850	11,115
	Medicare	15 (0.5 %)	575 (4 %)	DS	70 (1.8 %)	35 (0.7 %)	155 (1.4 %)
	Medicaid	1525 (50.2 %)	7420 (51.9 %)	280 (37.8 %)	1805 (45.8 %)	2050 (42.3 %)	5830 (52.5 %)
	Private	1210 (39.8 %)	5260 (36.8 %)	365 (49.3 %)	1770 (44.9 %)	2095 (43.2 %)	4390 (39.5 %)
	Self Pay/No Charge	60 (2 %)	390 (2.7 %)	DS	170 (4.3 %)	145 (3 %)	335 (3 %)
	Other Insurance	230 (7.6 %)	660 (4.6 %)	85 (11.5 %)	125 (3.2 %)	525 (10.8 %)	405 (3.6 %)
Median household income for patient's ZIP Code	Data available for $N =$	3020	14,160	730	3915	4780	10,995

(*continued on next page*)

Table 2 (*Continued*)

Type of Clefts		Cleft Palate Only $N = 17,355$		Cleft Lip Only $N = 4690$		Cleft Palate with Cleft Lip $N = 15,985$	
Primary or Secondary Diagnosis of Cleft Lip and/or Palate		Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis
Characteristic	Response	$N = 3045$	$N = 14,310$	$N = 740$	$N = 3950$	$N = 4860$	$N = 11,125$
	0 to 25th Percentile	825 (27.3 %)	4100 (29 %)	175 (24 %)	1030 (26.3 %)	1325 (27.7 %)	3520 (32 %)
	26th to 50th Percentile	760 (25.2 %)	3780 (26.7 %)	190 (26 %)	1020 (26.1 %)	1230 (25.7 %)	2895 (26.3 %)
	51st to 75th percentile	780 (25.8 %)	3580 (25.3 %)	160 (21.9 %)	945 (24.1 %)	1205 (25.2 %)	2485 (22.6 %)
	76th to 100th percentile	655 (21.7 %)	2700 (19.1 %)	205 (28.1 %)	920 (23.5 %)	1020 (21.3 %)	2095 (19.1 %)
Age in Years	Mean (Standard Error of Mean)	2.8 (0.27)	5.4 (0.29)	2.4 (0.65)	3.9 (0.44)	4.8 (0.29)	3.6 (0.22)

Note: Sum of hospitalizations with Cleft Palate Only ($N = 17,355$), Cleft Lip Only ($N = 4690$), and Cleft Palate with Cleft Lip (15,985) is 38,030 which is more than the actual total number of hospitalizations ($N = 37,895$: 8615 with primary diagnosis of Cleft Lip and/or Palate and 29,280 with secondary diagnosis of Cleft Lip and/or Palate) because 135 hospitalizations had more than one type of cleft mentioned.
DS – Discharge information suppressed since individual cell count is ≤10 (per HCUP-AHRQ data user agreement).

number of hospitalizations by each year varied slightly between the cleft types and primary/secondary diagnosis (was within a 0.3 % to 7.4 % range). Majority of Cleft Palate Only hospitalizations were females while males comprised of majority of Cleft Lip Only and Cleft Palate with Cleft Lip hospitalizations. Overall, whites were the predominating race across all cleft types. Southern regions accounted for the highest numbers of hospitalizations. Vast majority of hospitalizations with a secondary diagnosis of any of the Cleft types occurred on an emergency/urgent basis. Urban teaching hospitals accounted for a overwhelming majority of hospitalizations across all cleft types be it primary or secondary diagnosis. Medicaid and private insurance plans covered most numbers of hospitalizations across cleft types. The mean age of hospitalizations ranged from 2.4 years for primary diagnosis of Cleft Lip Only to 5.4 years for secondary diagnosis of Cleft Palate Only.

The common reasons for hospitalization amongst those with only a secondary diagnosis of any of the cleft types are presented in Table 3. Across all cleft types, "liveborn" was the most common reason for the hospitalization. Clearly, majority of hospitalizations were newborns who had a secondary diagnosis of any of the clefts.

The comorbid burden across different types of clefts and primary/secondary diagnosis of clefts are presented in Table 4. Overall, those hospitalizations with a secondary diagnosis of any of the clefts had a higher prevalence of comorbid conditions compared to those with a primary diagnosis of any of the clefts. Frequently occurring comorbid conditions included chronic pulmonary diseases, hypothyroidism, uncomplicated hypertension, obesity, and depression.

The disposition statuses of patients following hospitalization are presented in Table 5. A vast majority of those admitted primarily due to any of the cleft types were discharged routinely (ranging from 96 % of Cleft Palate Only hospitalizations to 99.3 % of Cleft Lip Only hospitalizations). This is in contrast to those with a secondary diagnosis of any of the clefts where routine discharge occurred in a range of 76.4 % for hospitalizations with Cleft Palate Only to 90 % for hospitalizations with Cleft Lip Only. Higher in-hospital mortality rates were observed in those with a secondary diagnosis of any of the cleft types compared to those with a primary diagnosis of any of the cleft types.

The total hospitalization charges (inflation adjusted to year 2022 $ value) for all the hospitalizations (with either primary or secondary diagnosis of any of the cleft types) across the entire United States during the study period was about $5 Billion and mean charge was $134,774. The total hospitalization days for the entire cohort of hospitalizations was 372,540 days (mean was 9.8 days). Across all cleft types, hospitalizations with a secondary diagnosis of any of the clefts had higher mean hospitalization charges and mean length of stay in hospital (Table 6).

Discussion

In this study we provide epidemiological estimates of hospitalization characteristics and outcomes of CLP. Any hospitalization that occurred with either a primary or secondary diagnosis of CLP were examined in the study and all outcomes were presented by type of cleft. Overall, Males and Whites comprised of about 52 % of all hospitalizations. Admissions to urban teaching hospitals predominated. These findings consistently align with previous reports showing higher hospitalization rates among males,[4,12,13] the White population,[12,14]and in urban teaching hospitals.[12,14,15]

Hospital outcomes for CLP varied substantially depending on whether it was recorded as a primary diagnosis or as a secondary diagnosis and by type of cleft (Cleft Palate Only, Cleft Lip Only or Cleft Palate with Cleft Lip). Overall, the mean age at hospitalization was higher amongst hospitalizations with secondary diagnosis of Cleft Palate Only and Cleft Lip Only when compared to hospitalizations with a primary diagnosis of these respective cleft types. The mean age of hospitalizations with a primary diagnosis of Cleft Palate with Cleft Lip was higher compared to hospitalizations with a secondary diagnosis of this type of

Table 3
Reasons for hospitalization in the cohort with a secondary diagnosis of cleft lip and/or palate.

Reasons for Hospitalization		Hospitalizations with Secondary Diagnosis of Cleft Palate Only $N = 14,310$	Hospitalizations with Secondary Diagnosis of Cleft Lip Only $N = 3950$	Hospitalizations with Secondary Diagnosis of Cleft Palate with Cleft Lip $N = 11,125$
Clinical Classification Software Code	Description			
END008	Malnutrition	200 (1.4 %)	Too low to report	125 (1.1 %)
INF002	Septicemia	275 (1.9 %)	Too low to report	Too low to report
INJ037	Complication of other surgical or medical care, injury, initial encounter	165 (1.1 %)	Too low to report	Too low to report
MAL001	Cardiac and circulatory congenital anomalies	270 (1.9 %)	Too low to report	130 (1.2 %)
MAL002	Digestive congenital anomalies	250 (1.7 %)	Too low to report	120 (1.1 %)
MAL007	Respiratory congenital malformations	155 (1.1 %)	Too low to report	Too low to report
MAL008	Musculoskeletal congenital conditions	220 (1.5 %)	Too low to report	Too low to report
MAL010	Other specified and unspecified congenital anomalies	690 (4.8 %)	Too low to report	Too low to report
MUS029	Disorders of jaw	170 (1.2 %)	Too low to report	800 (7.2 %)
NVS009	Epilepsy; convulsions	255 (1.8 %)	Too low to report	155 (1.4 %)
PNL001	Liveborn	5795 (40.5 %)	3025 (76.6 %)	6525 (58.6 %)
PNL006	Respiratory perinatal condition	215 (1.5 %)	Too low to report	Too low to report
PNL012	Neonatal digestive and feeding disorders	255 (1.8 %)	Too low to report	130 (1.2 %)
PNL013	Other specified and unspecified perinatal conditions	185 (1.3 %)	Too low to report	115 (1 %)
PRG016	Previous C-section	Too low to report	40 (1 %)	Too low to report
RSP002	Pneumonia (except that caused by tuberculosis)	150 (1.0 %)	Too low to report	Too low to report
RSP005	Acute bronchitis	360 (2.5 %)	Too low to report	180 (1.6 %)
RSP012	Respiratory failure; insufficiency; arrest	450 (3.1 %)	Too low to report	220 (2 %)
SYM016	Other general signs and symptoms	360 (2.5 %)	Too low to report	215 (1.9 %)

Note: Close to 500 different Clinical Classification Software Codes were used to identify the reasons for hospitalization in the cohort with a secondary diagnosis of Cleft Lip and/or Palate. The numbers of only those conditions that occurred in at least 1 % of the hospitalizations in the different cleft types are presented in the table to avoid potential patient identification.
Too low to report: refers to occurrences <1 %.

Table 4
Presence of Co-morbid conditions in hospitalizations by type of cleft.

Comorbid Condition	Cleft Palate Only Total $N = 17,355$		Cleft Lip Only Total $N = 4690$		Cleft Palate with Cleft Lip Total $N = 15,985$	
	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis
Alcohol Abuse	DS	60 (0.4 %)	DS	15 (0.4 %)	DS	30 (0.3 %)
Autoimmune Conditions	DS	55 (0.4 %)	DS	DS	15 (0.3 %)	DS
Leukemia	DS	20 (0.1 %)	DS	DS	DS	30 (0.3 %)
Lymphoma	DS	DS	DS	DS	DS	DS
Metastatic Cancer	DS	20 (0.1 %)	DS	DS	DS	DS
Solid Tumor without Metastasis, In Situ	DS	DS	DS	DS	DS	DS
Solid Tumor without Metastasis, Malignant	DS	35 (0.2 %)	DS	DS	DS	20 (0.2 %)
Dementia	DS	105 (0.7 %)	DS	DS	DS	DS
Depression	25 (0.8 %)	170 (1.2 %)	DS	35 (0.9 %)	45 (0.9 %)	130 (1.2 %)
Diabetes with Chronic Complications	DS	125 (0.9 %)	DS	30 (0.8 %)	DS	80 (0.7 %)
Diabetes without Chronic Complications	DS	100 (0.7 %)	DS	DS	20 (0.4 %)	45 (0.4 %)
Drug Abuse	20 (0.7 %)	100 (0.7 %)	DS	25 (0.6 %)	DS	50 (0.4 %)
Hypertension, Complicated	DS	250 (1.7 %)	DS	20 (0.5 %)	DS	75 (0.7 %)
Hypertension, Uncomplicated	20 (0.7 %)	525 (3.7 %)	DS	70 (1.8 %)	40 (0.8 %)	165 (1.5 %)
Chronic Pulmonary Disease	100 (3.3 %)	895 (6.2 %)	DS	55 (1.4 %)	175 (3.6 %)	225 (2 %)
Obesity	15 (0.5 %)	300 (2.1 %)	DS	80 (2 %)	50 (1 %)	145 (1.3 %)
Peripheral Vascular Disease	DS	200 (1.4 %)	DS	15 (0.4 %)	DS	55 (0.5 %)
Hypothyroidism	30 (1 %)	385 (2.7 %)	DS	30 (0.8 %)	75 (1.5 %)	250 (2.2 %)
Other Thyroid Disorders	DS	55 (0.4 %)	DS	DS	DS	DS

DS – Discharge information suppressed since individual cell count is ≤10 (per HCUP-AHRQ data user agreement).

Table 5
Disposition status following hospitalization by type of cleft.

Disposition Status	Cleft Palate Only Total N = 17,355		Cleft Lip Only Total N = 4690		Cleft Palate with Cleft Lip Total N = 15,985	
	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis
Routine Discharge	2920 (96 %)	10,940 (76.4 %)	735 (99.3 %)	3590 (90.9 %)	4760 (97.9 %)	8865 (79.7 %)
Transferred to a Short-Term Hospital	DS	1420 (9.9 %)	DS	115 (2.9 %)	25 (0.5 %)	930 (8.4 %)
Transfer Other: Includes Skilled Nursing Facility, Intermediate Care Facility, Another Type of Facility	20 (0.7 %)	460 (3.2 %)	DS	45 (1.1 %)	15 (0.3 %)	235 (2.1 %)
Home Health Care	90 (3 %)	1115 (7.8 %)	DS	135 (3.4 %)	60 (1.2 %)	540 (4.9 %)
Discharged Against Medical Advice	DS	35 (0.2 %)	DS	DS	DS	15 (0.1 %)
Died	DS	335 (2.3 %)	DS	55 (1.4 %)	DS	540 (4.9 %)

Note: Sum of individual counts may not add up to total N for each cleft type because of missing values and some cells having too few counts that cannot be reported.
DS – Discharge information suppressed since individual cell count is ≤10 (per HCUP-AHRQ data user agreement).

Table 6
Hospital charges and length of stay.

Disposition Status	Cleft Palate Only Total N = 17,355		Cleft Lip Only Total N = 4690		Cleft Palate with Cleft Lip Total N = 15,985	
	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis	Primary Diagnosis	Secondary Diagnosis
Mean Charges (Standard Error of Mean)	$70,650 (4537)	$197,988 (9834)	$48,292 (2302)	$67,895 (10,558)	$67,067 (3405)	$129,295 (8676)
Mean Length of Stay in Hospital (Standard Error of Mean)	3.7 days (0.39)	15.1 days (0.57)	1.2 days (0.05)	6.2 days (0.59)	2.7 days (0.21)	9.7 days (0.50)

Cleft. As our study did not stratify hospitalizations by age group, these admissions may reflect a spectrum of interventions[3] from infancy through adulthood. Surgical repair of the lip and palate remains the cornerstone to CLP management and the optimal timing of these interventions continues to be debated. Cleft lip repair is generally recommended between 3 and 5 months of age, while the timing of cleft palate repair differs based on various protocols seeking to optimize speech outcomes while minimizing the risk of maxillary hypoplasia.[16]

In our study, the most common co-morbidity was chronic pulmonary disease. Respiratory complications in those with CLP have been documented in the literature.[17–19] Chronic pulmonary disease in this population may present along a spectrum, ranging from mild asthma to severe chronic obstructive pulmonary disease necessitating advanced airway and mechanical ventilation.[20] In children, cleft deformities associated with other congenital anomalies, respiratory conditions, or a history of difficult intubation predispose to airway challenges and pulmonary complications.[6,18,21] Additionally, studies suggest that a wide cleft increases susceptibility to pathogens entering the upper respiratory tract, thereby elevating the risk of peri-operative respiratory complications in infants with cleft lip and palate.[18,19,22]

While it is not possible to identify reasons for the higher prevalence of chronic pulmonary disease, the findings were consistent with Bell et al., who saw greater risk of respiratory conditions requiring inpatient care in patients with clefts at 12 years and younger.[19] We can only speculate that these hospitalizations may have developed respiratory or other complications following surgical treatment for cleft lip and palate. This is consistent with findings from a previous study[20] where children with a cleft palate showed a higher incidence rate for hospitalizations due to airway infections both before and after palate repair. These patients also showed the need for postoperative intubation compared with controls. Postoperative airway complications in CLP patients are well recognized, particularly after pharyngeal flap or palate repair and in syndromic cases such as Pierre Robin sequence or Franceschetti syndrome.[18,23]

Additionally, hypothyroidism was identified in 2 % of all hospitalizations. Association of congenital hypothyroidism with orofacial clefts has been reported in the literature as part of certain syndromes or shared developmental pathways.[24] These findings necessitate the need for considering endocrinological evaluation as part of comprehensive CLP care.

Patients born with CLP exhibit poor confidence, elevated levels of anxiety and depression[25,26] and a higher risk of hospitalization for mental health disorders.[27] In our study, 1.1 % of all hospitalizations had depression. Based on these findings incorporating routine psychological support for patients affected with CLP from an early age is strongly recommended to help manage the mental health challenges associated with their treatment. It should be noted that the prevalence of depression in the present study is lower than global prevalence of depression. However, the present study's CLP population is comprised of a much younger cohort compared to the global estimate studies on depression.[28,29]

Overall, hospitalizations that had a secondary diagnosis of any of the cleft types had higher mortality rates compared to hospitalizations with a primary diagnosis of any of the cleft types. We speculate that the higher comorbid burden in the secondary diagnosis cohort might have contributed to the higher mortality rates. It has been reported in literature that the presence of additional comorbid conditions is a primary risk factor for mortality.[30] Children with CLP and associated co-morbidities are reported to have a 20-fold increased risk of death across all cleft phenotypes.[5] Although data on CLP-related mortality remain limited and often lack detail, understanding the factors contributing to mortality is essential for planning multidisciplinary care and informed communication with families.

Hospitalizations with a secondary diagnosis of any of the clefts had higher mean charges and length of stay in hospital when compared to hospitalizations with a primary diagnosis of any of the cleft types. Length of stay can be used as a proxy for efficiency of care, and extended hospitalizations may reflect postoperative complications, cleft severity, additional congenital anomalies, or variations in clinician practice.[4]

The results of our study should be interpreted keeping several limitations in perspective. We did not account for cleft severity or the presence of syndromes, which may independently contribute to comorbidities and adverse outcomes. Our data lack details on age-specific interventions, and the reported mean age may not accurately reflect the timing or reason for hospitalization due to limited granularity inherent in studies using large databases like the NIS. The specific causes of mortality

among patients with any of the clefts as a secondary diagnosis are unknown, preventing full explanation of these outcomes or assessment. As with all large administrative databases, coding errors may be present. Cost data were limited to hospitalization charges and did not include professional fees, costs associated with medications or post-discharge medical care costs. Furthermore, the database only captures inpatient data, and we cannot determine whether co-morbidities were associated with CLP as a syndrome or occurred independently. Finally, we only present descriptive statistics in the present study and did not conduct inferential statistics. As mentioned earlier, we included all cleft types and included hospitalizations that were primarily attributed to any of the clefts (primary diagnosis) as well hospitalization that had a secondary diagnosis of any of the clefts. Conducting statistical analysis to compare any outcomes across these widely heterogenous groups would not be meaningful. The regression models would not converge because of the low cell counts that are found at different level of potential predictor variables across different types of clefts.

It is also worth noting that the study period included the COVID-19 pandemic, which could have influenced results such as length of stay and charges, as pandemic-related delays have been reported with CLP care.[31] Future research can further our insights into the complex interplay of the clinical, socio-demographic, hospital and care delivery-related variables in comprehensive CLP care. Studies utilizing multivariable regression analyses to quantify the impact of the various clinical factors are warranted. Quantitative analysis of complementary nationwide databases such as the National Surgical Quality Improvement Program can be considered to include more detailed patient-level variables not present in NIS datasets. Furthermore, prospective studies can be designed to confirm the findings of nationwide retrospective cross-sectional studies.

Despite the limitation, our study findings provide the most updated nationally representative estimates of hospitalizations associated with CLP and the associated outcomes. There is lack of data on these estimates at a national level. Taken all together, this study shows that hospitalizations with a secondary diagnosis of any of the cleft types showed greater mortality, longer length of stay, and higher hospital charges than hospitalizations with a primary admission diagnosis of any of the cleft types. It must be emphasized to key stakeholders including families, care teams, and health system and governmental payers, that cleft care is a longitudinal multidisciplinary continuum that extends beyond the initial repair. Aligning care coverage and capacity accordingly are essential to enable timely high-quality care. Because of the higher frequency of negative outcomes and longer length of stay and charges in the secondary diagnosis group, explicitly accounting for these episodes through targeted resource allocation can help reduce avoidable strains on the healthcare system.

Conclusions

Our study provided epidemiological estimates of hospitalization characteristics and outcomes of CLP related admissions in the United States during the years 2020 to 2022. Hospitalizations with any of the cleft types as a secondary diagnosis demonstrated higher mortality, longer lengths of stay, and greater hospital charges compared to hospitalizations with any of the clefts as a primary diagnosis. A firm understanding of these findings along with recognition of the longitudinal nature of cleft care should stimulate policy changes aimed at targeted resource allocation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Dr. Veerasathpurush Allareddy serves as Associate Editor of Seminars in Orthodontics and is the Guest Editor for the 5th Dr. Thomas Graber International Symposium

Dr. Min Kyeong Lee serves on the Editorial Board of Seminars in Orthodontics and the Guest Editor for the 5th Dr. Thomas Graber International Symposium.

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CRediT authorship contribution statement

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References

1. Leslie EJ, Carlson JC, Shaffer JR, et al. A multi-ethnic genome-wide association study identifies novel loci for non-syndromic cleft lip with or without cleft palate on 2p24.2, 17q23 and 19q13. *Hum Mol Genet*. 2016;25(13):2862–2872. https://doi.org/10.1093/hmg/ddw104.
2. Dixon MJ, Marazita ML, Beaty TH, Murray JC. Cleft lip and palate: synthesizing genetic and environmental influences. *Nat Rev Genet*. 2011;12(3):167–178. https://doi.org/10.1038/nrg2933.
3. Yates D, Allareddy V, Caplin J, Yadav S, Markiewicz MR. An overview of timeline of interventions in the continuum of cleft lip and palate care. *Oral Maxillofac Surg Clin N Am*. 2020;32(2):177–186. https://doi.org/10.1016/j.coms.2020.01.001.
4. Lo JYJ, Kilpatrick N, Jacoby P, Slack-Smith LM. Description of total population hospital admissions for cleft lip and/or palate in Australia. *BMC Oral Health*. 2015;15(1):156. https://doi.org/10.1186/s12903-015-0144-1.
5. Plonkowski AT, Naidu P, Celie KB, et al. Mortality in cleft lip and palate patients: a systematic review and meta-analysis. *Plast Reconstr Surg – Glob Open*. 2025;13(5):e6721. https://doi.org/10.1097/GOX.0000000000006721.
6. Desalu I, Adeyemo W, Akintimoye M, Adepoju A. Airway and respiratory complications in children undergoing cleft lip and palate repair. *Ghana Med J*. 2010;44(1):16–20. https://doi.org/10.4314/gmj.v44i1.68851.
7. Stanton EW, Manasyan A, Roohani I, et al. A nationwide analysis of the impact of cardiopulmonary anomalies on cleft palate surgical outcomes. *Cleft Palate Craniofacial J*. 2025;62(8):1346–1351. https://doi.org/10.1177/10556656241258525.
8. Weiss J, Kotelchuck M, Grosse SD, et al. Hospital use and associated costs of children aged zero-to-two years with craniofacial malformations in Massachusetts. *Birt Defects Res Clin Mol Teratol*. 2009;85(11):925–934. https://doi.org/10.1002/bdra.20635.
9. Boulet SL, Grosse SD, Honein MA, Correa-Villaseñnor A. Children with orofacial clefts: health-care use and costs among a privately insured population. *Public Health Rep*. 2009;124(3):447–453. https://doi.org/10.1177/003335490912400315.
10. HCUP-US NIS overview. Accessed September 15, 2024. https://hcup-us.ahrq.gov/nisoverview.jsp.

11. U.S. Bureau of Labor Statistics. Consumer price index: medical care. WWW link is https://www.bls.gov/cpi/factsheets/medical-care.htm. Date of access is 04/07/2025 - Google Search. Accessed September 8, 2025.
12. Lee MK, Yen SLK, Allareddy V. Hospitalization outcomes of cleft lip repair in neonates across the United States. *Cleft Palate-Craniofacial J Publ Am Cleft Palate-Craniofacial Assoc*. 2018;55(4):528–535. https://doi.org/10.1177/1055665617726531.
13. Peck CJ, Parsaei Y, Jazayeri HE, et al. A National assessment of racial and ethnic disparities in cleft lip repair. *Plast Reconstr Surg*. 2024;154(5):1058–1066. https://doi.org/10.1097/PRS.0000000000011203.
14. Allareddy V, Turkistani K, Nanda V, Allareddy V, Gajendrareddy P, Venugopalan SR. Factors associated with hospitalization charges for cleft palate repairs and revisions. *J Oral Maxillofac Surg J Am Assoc Oral Maxillofac Surg*. 2012;70(8):1968–1977. https://doi.org/10.1016/j.joms.2011.07.026.
15. Metalwala Z, Okunseri C, Fletcher S, Allareddy V. Orthognathic surgical outcomes in patients with and without craniofacial anomalies. *J Oral Maxillofac Surg J Am Assoc Oral Maxillofac Surg*. 2018;76(2). https://doi.org/10.1016/j.joms.2017.09.023. 436.e1-436.e8.
16. Naidu P, Yao CA, Chong DK, Magee WPI. Cleft palate repair: a history of techniques and variations. *Plast Reconstr Surg – Glob Open*. 2022;10(3):e4019. https://doi.org/10.1097/GOX.0000000000004019.
17. Kantar RS, Cammarata MJ, Rifkin WJ, Plana NM, Diaz-Siso JR, Flores RL. Outpatient versus inpatient primary cleft lip and palate surgery: analysis of early complications. *Plast Reconstr Surg*. 2018;141(5):697e–706e. https://doi.org/10.1097/PRS.0000000000004293.
18. Kulkarni KR, Patil MR, Shirke AM, Jadhav SB. Perioperative respiratory complications in cleft lip and palate repairs: an audit of 1000 cases under "Smile Train Project. *Indian J Anaesth*. 2013;57(6):562–568. https://doi.org/10.4103/0019-5049.123328.
19. Bell J, Nassar N, Turner R, et al. Hospitalisations up to adulthood for children born with orofacial clefts. *J Paediatr Child Health*. 2016;52(4):441–448. https://doi.org/10.1111/jpc.13024.
20. Laager R, Gregoriano C, Hauser S, et al. Hospitalization trends for airway infections and In-hospital complications in cleft lip and palate. *JAMA Netw Open*. 2024;7(9):e2428077. https://doi.org/10.1001/jamanetworkopen.2024.28077.
21. Jackson O, Basta M, Sonnad S, Stricker P, Larossa D, Fiadjoe J. Perioperative risk factors for adverse airway events in patients undergoing cleft palate repair. *Cleft Palate Craniofacial J*. 2013;50(3):330–336. https://doi.org/10.1597/12-134.
22. Takemura H, Yasumoto K, Toi T, Hosoyamada A. Correlation of cleft type with incidence of perioperative respiratory complications in infants with cleft lip and palate. *Paediatr Anaesth*. 2002;12(7):585–588. https://doi.org/10.1046/j.1460-9592.2002.00906.x.
23. Antony AK, Sloan GM. Airway obstruction following palatoplasty: analysis of 247 consecutive operations. *Cleft Palate-Craniofac J Publ Am Cleft Palate-Craniofacial Assoc*. 2002;39(2):145–148. https://doi.org/10.1597/1545-1569_2002_039_0145_aofpao_2.0.co_2.
24. Akin M, Kurtoğlu S, Sarici D, et al. Endocrine abnormalities of patients with cleft lip and/or cleft palate during the neonatal period. *Turk J Med Sci*. 2014;44(4):696–702. https://doi.org/10.3906/sag-1303-89.
25. Berg E, Haaland ØA, Feragen KB, et al. Health status among adults born with an oral cleft in Norway. *JAMA Pediatr*. 2016;170(11):1063–1070. https://doi.org/10.1001/jamapediatrics.2016.1925.
26. Nicholls W, Harper C, Robinson S, Persson M, Selvey L. Adult-specific life outcomes of cleft lip and palate in a Western Australian cohort. *Cleft Palate Craniofacial J*. 2018;55(10):1419–1429. https://doi.org/10.1177/1055665618768540.
27. Christensen K, Mortensen PB. Facial clefting and psychiatric diseases: a follow-up of the Danish 1936–1987 Facial cleft cohort. *Cleft Palate Craniofacial J*. 2002;39(4):392–396. https://doi.org/10.1597/1545-1569_2002_039_0392_fcapda_2.0.co_2.
28. Lu B, Lin L, Su X. Global burden of depression or depressive symptoms in children and adolescents: a systematic review and meta-analysis. *J Affect Disord*. 2024;354:553–562. https://doi.org/10.1016/j.jad.2024.03.074.
29. Shorey S, Ng ED, Wong CHJ. Global prevalence of depression and elevated depressive symptoms among adolescents: a systematic review and meta-analysis. *Br J Clin Psychol*. 2022;61(2):287–305. https://doi.org/10.1111/bjc.12333.
30. Huang RS, Mihalache A, Wong Riff KWY. Cleft lip and/or palate mortality trends in the USA: a retrospective population-based study. *BMJ Paediatr Open*. 2024;8(1):e002305. https://doi.org/10.1136/bmjpo-2023-002305.
31. Bruce MK, Pfaff MJ, Anstadt EE, Losee JE, Goldstein JA. The impact of the COVID-19 Pandemic on Cleft care. *Plast Reconstr Surg Glob Open*. 2021;9(4):e3587. https://doi.org/10.1097/GOX. 0000000000003587.