TRUVETA
Saving Lives with Data

moderna®
this changes everything

Supporting therapy adoption:
the power of regulatory-grade EHR data and clinical expert-led AI

May 6, 2024

Ryan Ahern, MD, MPH
Chief Medical Officer & Co-founder
Truveta

Anita Loughlin, PhD
Director of Epidemiology, Rare Disease
Moderna

TRUVETA moderna

More than 30 health systems committed to Saving Lives with Data

18% of daily clinical care across the country

Providence
ADVOCATE HEALTH
Trinity Health
Tenet Health
Northwell Health
AdventHealth
Baptist Health
BaylorScott&White HEALTH
BON SECOURS MERCY HEALTH
CommonSpirit
HAWAI'I PACIFIC HEALTH
HealthPartners
HENRY FORD HEALTH
HONORHEALTH
Lehigh Valley Health Network
MEMORIAL HERMANN
Inova
MedStar Health
NOVANT HEALTH
MetroHealth
Ochsner Health
Premier Health
Saint Luke's
SANFORD HEALTH
Sentara
Texas Health Resources
TriHealth
UnityPoint Health
Virtua Health
WellSpan HEALTH

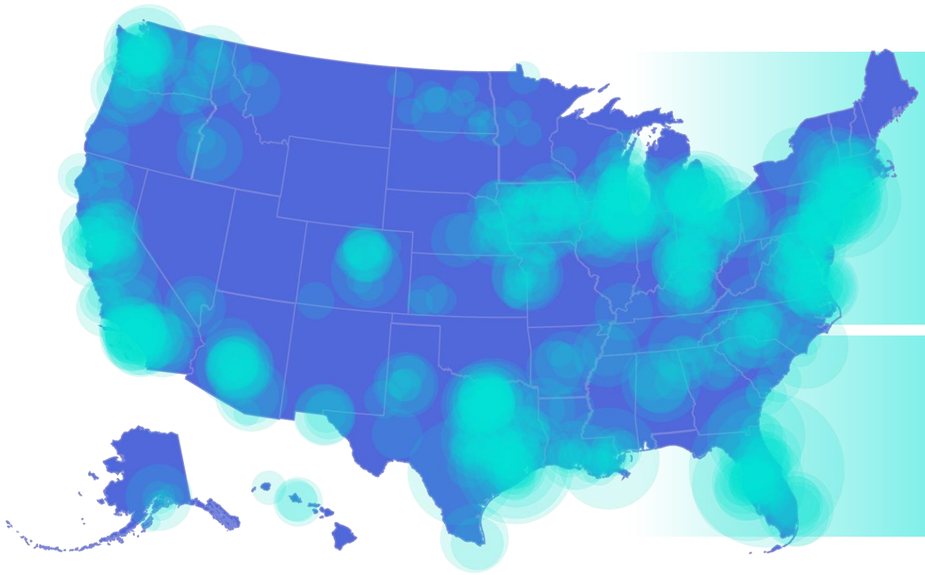
Truveta Data: Complete, timely, clean, and representative EHR data

Complete
EHR, notes, and imaging data linked with claims, SDOH, and mortality

Timely
Daily updates across care settings

Clean
Accurately normalized without commercial bias

Representative
Patients across the US, including 800 hospitals, and 20,000 clinics



Semi-structured data
Diagnosis (SNOMED, ICD)
Procedure (CPT,HCPCS)
Medication (RXNORM,NDC)
Labs (LOINC,UCUM)
Immunizations (CVX)
Implanted/Explanted Device (UDI)
Care setting
Pharmacy

Unstructured data
Clinical notes
Images, including MRI, CT, X-ray, ultrasound, mammogram, PET, and nuclear medicine

Social drivers of health

Claims

Mortality

Billions of data points normalized with clinical expert-led AI

Trained on unprecedented data

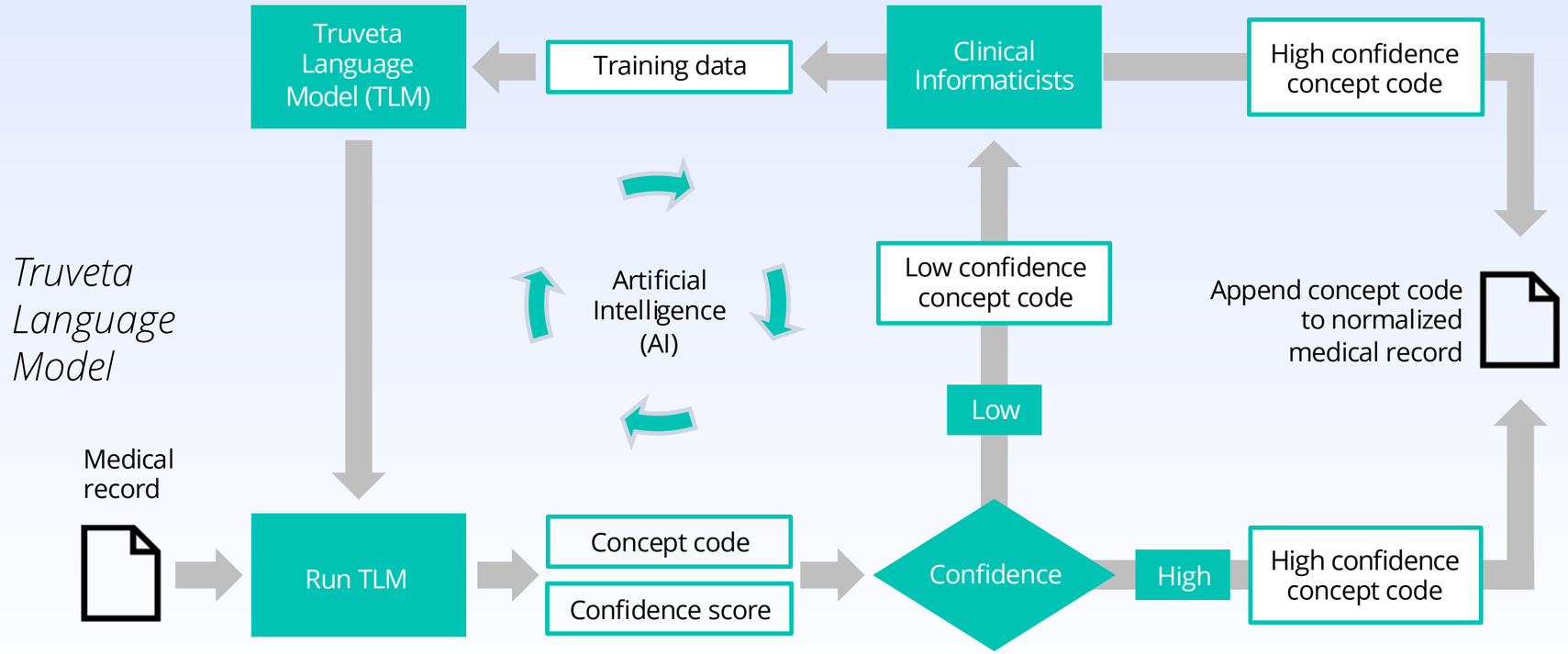
Truveta Language Model (TLM) is trained on more than 100M patient journeys

Clinical experts in the loop

Reviewed and refined for accuracy by a team of clinical experts

Greater than 92% accuracy[1,2]

Across diagnoses, medications, clinical observations, lab results, etc.



TRUVETA

1. Truveta Mapper: A Zero-shot Ontology Alignment Framework, 2. Truveta Language Model

Regulatory-grade EHR data enabling scientifically rigorous research

Life science

Safety	HEOR	Clinical trials	R&D	Commercial
Fulfill post-market safety commitments with regulatory-grade data updated daily	Establish clinical and economic differentiation to accelerate therapy adoption	Supplement trial evidence with regulatory-grade real-world arms	Train AI models with complete, representative, and clean real-world data	Track daily market share and supply chain shortages

Government / academic orgs

Public health
Monitor daily disease trends and identify health disparities

Health systems

Care quality
Monitor patient outcomes daily and drive evidence-based decisions

TRUVETA

Case study

Understanding the burden of a rare disease

Research team:
Wei-Chun (Serena) Hsu, MS, Manager, Real World Evidence Analytics, Moderna
Anita Loughlin, PhD, Director of Epidemiology, Rare Disease, Moderna

Moderna is committed to researching and developing mRNA therapies

moderna®

- Pharmaceutical and biotech company focused on mRNA therapeutics for:
  - rare disease
  - oncology
  - cardiovascular
  - autoimmune
  - infectious disease
- For rare disease, focused on restoring the activity of missing enzymes

Ornithine transcarbamylase deficiency (OTCD)

- Rare, X-linked genetic enzyme deficiency
- Results in the accumulation of nitrogen, in the form of ammonia, a neurotoxin
- Symptoms range from neurologic (headache, vomiting) to acute (seizure, coma) to long-term (developmental delays)
- Management involves protein-restricted diets, amino acid supplementation, nitrogen scavengers; liver transplants are curative but not widely accessible

In-depth knowledge of OTCD is limited and patient management varies widely

Moderna research objectives:

- Understand patients affected by OTCD
- Describe burden of symptoms
- Understand treatment patterns, diet
- Identify potential trial endpoints

Real-world data requirements:

- **Large dataset** with sufficient OTCD population
- **Patient-level data**, including labs (e.g., serum/plasma ammonia, urinary orotic acid, LFTs), supplement/medication use
- Access to **clinical notes** (for diet, symptoms, events, triggers)

Accurately identifying patients with OTCD in the absence of a diagnostic code

- No ICD-10 code corresponding to OTCD
- Normalized health system text strings to SNOMED codes for precise identification of patients

Overview of health system terms mapped to codes for OTCD

Health System Term	CodeSystem	ConceptCode	ConceptName
OTC (ornithine transcarbamoylase deficiency) (HCC) | ICD10|E72.4	ICD10CM	E72.4	Disorders of ornithine metabolism
	SNOMED CT	80908008	Ornithine carbamoyltransferase deficiency
Disorders of ornithine metabolism | ICD10|E72.4	ICD10CM	E72.4	Disorders of ornithine metabolism
	SNOMED CT	237928008	Disorder of ornithine metabolism
Disorders of ornithine metabolism (HCC)| ICD10|E72.4	ICD10CM	E72.4	Disorders of ornithine metabolism
	SNOMED CT	237928008	Disorder of ornithine metabolism
Ornithine transcarbamoylase deficiency (HCC) | ICD10|E72.4	ICD10CM	E72.4	Disorders of ornithine metabolism
	SNOMED CT	80908008	Ornithine carbamoyltransferase deficiency
OTC (ornithine transcarbamoylase deficiency) | ICD10|E72.4	ICD10CM	E72.4	Disorders of ornithine metabolism
	SNOMED CT	80908008	Ornithine carbamoyltransferase deficiency

Using clinical expert-led AI to extract OTCD symptoms from clinical notes

[Location] FOLLOW UP Patient Name: [Name] | Age: [Age] y.o. | DOB: [Date] | Medical Record Number: [MRN] | Author: [Provider], CPNP-PC | Date of Encounter: [Date]

SUBJECTIVE: Location of consult: Telehealth (video capability) PARTICIPANTS: [Name] (patient), [Name] ([Relationship]), [Provider] (RN), and [Provider] (NP).

CHIEF COMPLAINT: Palliative Care with Ornithine transcarbamylase deficiency. Primary concerns and goals of patient and family: [Relationship] concerned how [Gender] own surgery for colon cancer on [Date] will affect [Name]. [Relationship]'s goals for [Gender] are to be happy and healthy.

HPI: [Name] is a [Age] y.o. [Gender] with ornithine transcarbamyase deficiency, stroke, refractive seizure disorder, refractory movement and sleep disorder, and chronic emesis with GT dependence. Stressors, including emesis and surgery, can trigger a metabolic crisis. [Relationship] to get colon resection and hysterectomy; will need to be admitted the night before for supportive IVF. Looking at a 3-7d hospital stay; never been away from [Name] for this long. Getting things organized before the surgery (med refills, nails/ hair/ wax). Difficulty getting weekend [Location] for [Name]; [Relationship] to get [Gender] own caregiver separately. [Relationship] to help. [Relationship] requested help with advanced directives form gave [Gender]. No changes to sz activity, 1-2/d, seconds at a time, fine while asleep, scares [Gender] when awake - [Relationship] not worried, will bring up next neuro visit. [Gender] tolerates [Gender] home-blended diet (Cyclinex-1 180g, Neocate Jr 110g, Essential amino acid mix 14g, Polycal 175g + water for final vol of 2000 ml) given 400ml over 1h 5x/d + free water 500ml/d via GT. Has 3-4 wet diapers/d and daily BMs. No pain concerns. [Gender] sleeps well on Melatonin 10mg qhs and Trazodone 50mg qpm, but will sometimes hurt [Gender] skin while crawling into bed with [Relationship] or end up somewhere else. [Relationship] will trade in car that just returned from shop following an accident for a van, and will look at van lift estimates. Transition to Kate Farms formula for [Name] was postponed initially due to accident. [Relationship] currently not working due to dx/ so many appointments; work raised money for [Relationship], and friend is paying for dog daycare. Last hosp for [Name] was at [Location] [Date] for general weakness, increased seizure frequency, vomiting, and constipation.

Objective:
VITALS: There were no vitals taken for this visit. [Location] visit [Date] - BP 110/72, P 91, T 98.1F, Wt 57.3kg.
ASSESSMENT & PLAN: 1. Palliative care patient w/ Ornithine transcarbamylase deficiency - explored [Relationship]'s emotions re [Gender] surgery. Appreciated [Relationship] getting everything in order. Has a good sense of humor; doing self-care with exercise. RN to f/u with agency to help with weekend [Location] for [Name]. Encouraged more progressive boundaries with [Name] now re climbing on top of [Relationship] for hugs as [Gender] will not be able to post surg. Will f/u with [Location] to discuss [Relationship]'s advanced directives. Encouraged [Relationship] to focus on recovering after surg before addressing things like van lift from Regional Center; pt is stable. Acknowledged [Gender] does not want to be a burden - reframed that [Gender] is being too hard on [Gender]self and that [Relationship] would take great care of [Gender] out of love. 2. Seizures - recommended bringing up adjusting doses to avoid daytime sz to Neuro. 3. Skin integrity - [Relationship] says [Gender] will not tolerate gloves; discussed clothing adjustments or additional floor accommodations to prevent skin injury when crawling. May also use bed alarm if worried about safety when crawling in the middle of the night. 4. Feedings - recommend formula transition after [Relationship]'s surgery as it may be a stressful event for patient as well. 1. Developmental Age: Developmental delay with no milestones met, due to diagnosis. 2. Developmental Stage/needs: total care needs, Gtube dependent and No change since prior encounter. 3. Learning or developmental disabilities: Yes and No change since prior encounter 4. Level of Function related to growth and development:: Non verbal, Non ambulatory, Incontinent of bladder , Incontinent of bowel and No change since prior encounter 5. Cognitive needs: severely intellectually deficient (SID) 6. Immunization status: up to date 7. Symptom(s) addressed: seizures, feedings and skin integrity 8. Family's perception of patient's pain: none. 9. PAINAD (if applicable) (.cbpcpainad): NA. SAFETY/

Truveta Language Model (TLM)

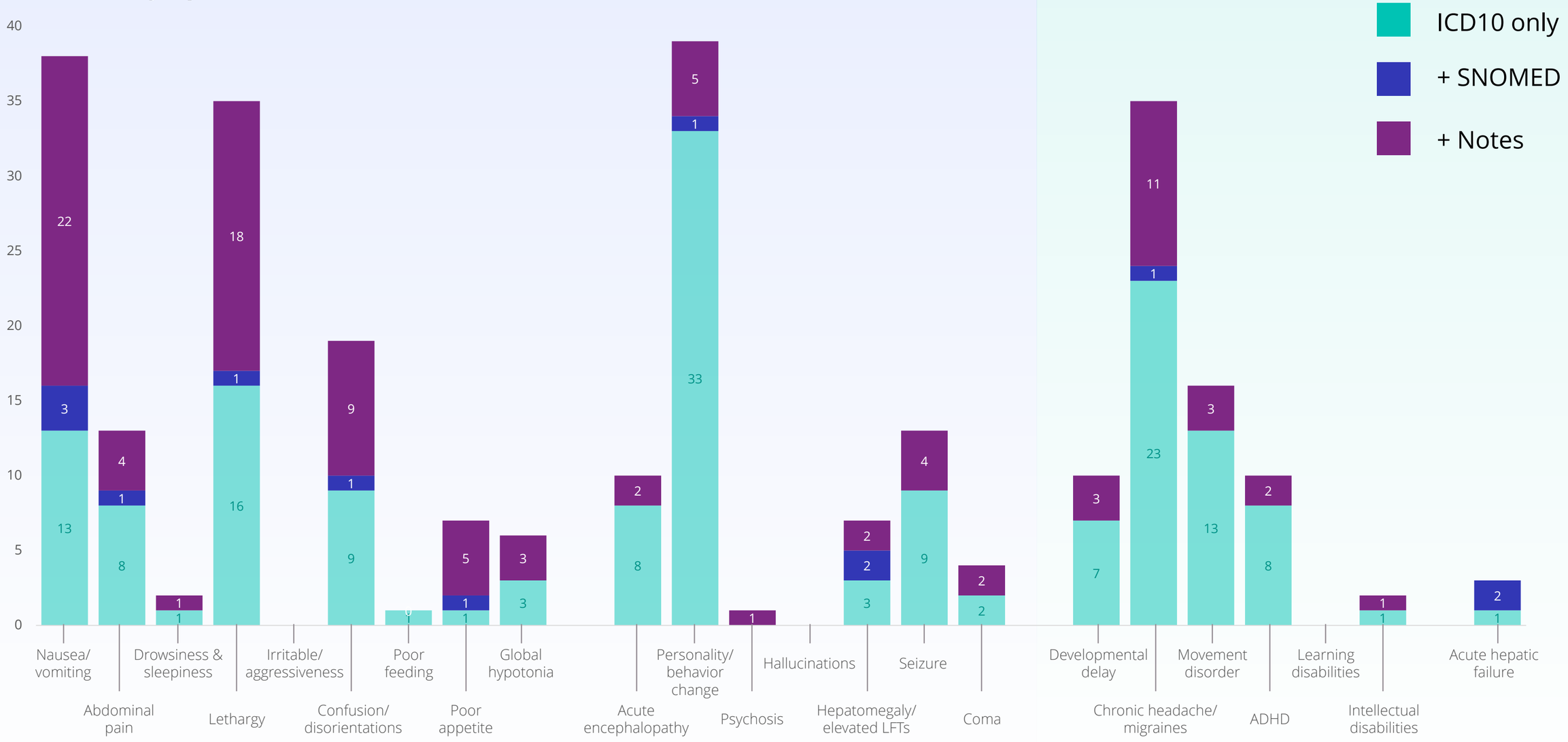

```
{
    "visit_date": "-",
    "signature_date": "-",
    "symptoms_diagnoses": [
        {
            "name": "Ornithine transcarbamylase deficiency",
            "date": "-",
            "temporality": "current",
            "status": "positive"
        },
        {
            "name": "stroke",
            "date": "-",
            "temporality": "historical",
            "status": "positive"
        },
        {
            "name": "refractive seizure disorder",
            "date": "-",
            "temporality": "current",
            "status": "positive"
        },
        {
            "name": "refractory movement disorder",
            "date": "-",
            "temporality": "current",
            "status": "positive"
        },
        {
            "name": "sleep disorder",
            "date": "-",
            "temporality": "current",
            "status": "positive"
        },
        {
            "name": "chronic emesis",
            "date": "-",
            "temporality": "current",
            "status": "positive"
        {
            "name": "general weakness",
            "date": "-",
            "temporality": "historical",
            "status": "positive"
        },
        {
            "name": "increased seizure frequency",
            "date": "-",
            "temporality": "historical",
            "status": "positive"
        },
        {
            "name": "vomiting",
            "date": "-",
            "temporality": "historical",
            "status": "positive"
        },
        {
            "name": "constipation",
            "date": "-",
            "temporality": "historical",
            "status": "positive"
        },
{
    "name": "pain",
    "date": "-",
    "temporality": "current",
    "status": "negative"
},
{
    "name": "severely intellectually deficient (SID)",
    "date": "-",
    "temporality": "current",
    "status": "positive"
},
{
    "name": "developmental delay with no milestones met",
    "date": "-",
    "temporality": "current",
    "status": "positive"
},
```


TRUVETA moderna

All notes fully PHI redacted

Estimating OTCD symptom burden by leveraging clinical notes

Occurrence of symptoms at baseline (n=102)

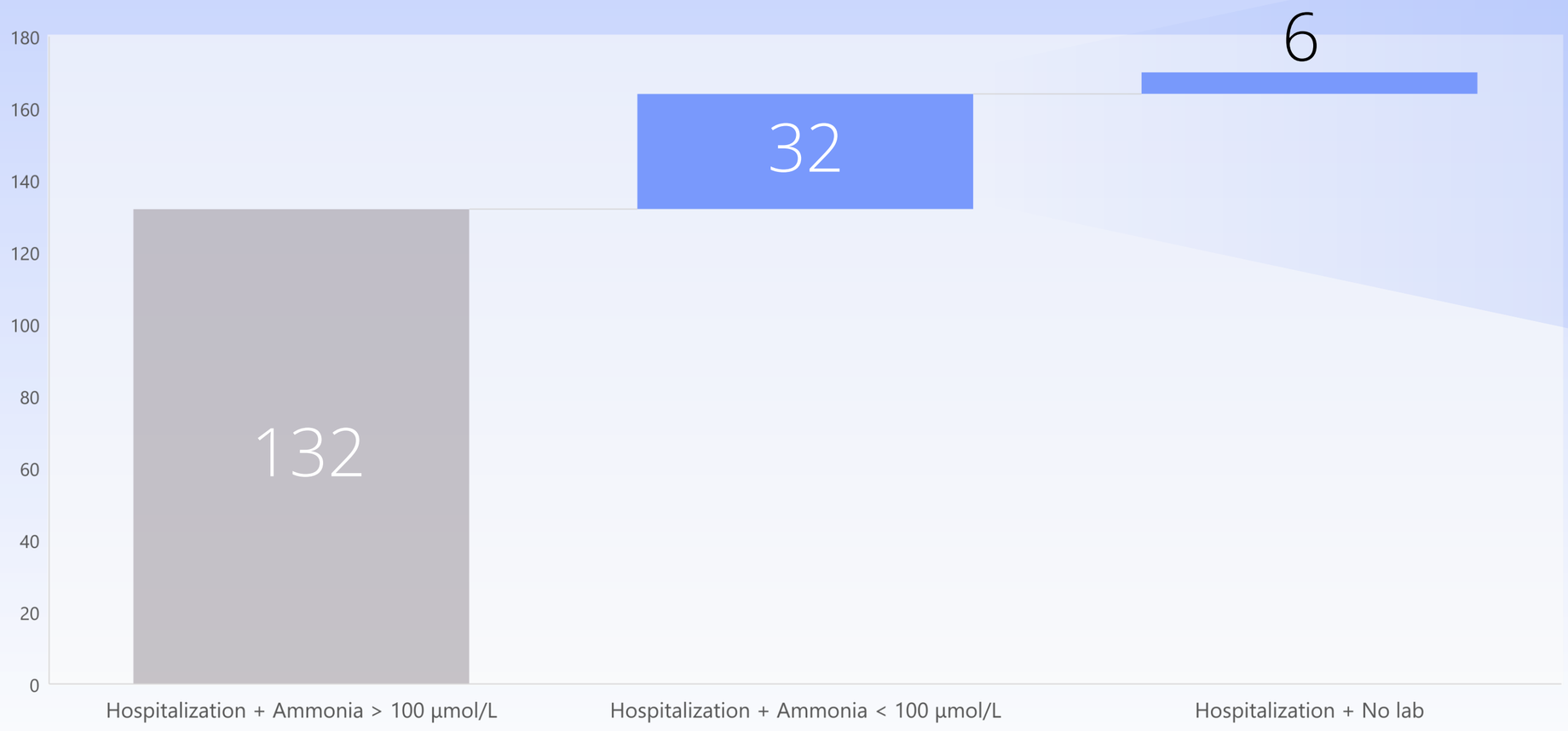


Symptoms associated with elevated ammonia

Long-term outcomes

Capturing 29% more hyperammonemia events (HAEs) using AI

Detecting HAEs among hospitalized patients



From structured/ semi-structured data

From unstructured data (notes)

29% increase

38 additional HAE events captured based on notes

TRUVETA moderna

Summarizing dietary patterns and understanding variability by cohort

Formatting of this note is different from the original. Clinical Nutrition Note - Genetics Assessment: [Name] is a [Age] y.o. [Gender] that is here for the following principal problem: Patient Active Problem List Diagnosis Late onset ornithine transcarbamylase deficiency syndrome Gastroesophageal reflux disease Hypertriglyceridemia Pertinent medical and nutritional information: [Name] had a prostatectomy earlier this month for cancer. Fasted 36 hours prior to surgery. Surgeons were aware of [Gender] condition. RN researched it and anesthesiologist and surgeon took it under consideration. [Gender] doesn'nt believe [Gender]'ll need other medical therapies to treat it. [Gender] hasn't had any concerns after surgery. [Gender] says [Gender] can tell if [Gender] has a little too much protein- [Gender] will feel foggy or fuzzy. [Gender] limits protein by adapting meals (removing meat from a sandwich, etc). [Gender] doesn't count protein , but [Gender] thinks [Gender] gets ~60 g of protein by eating familiar foods. Food allergy: NKFA Anthropometrics: Weight: 90.9 kg (200 lb 6.4 oz) ([Date]) Weight for Age: Facility age limit for growth percentiles is 20 years. Weight Change: -1.6 kg Height/Length for Age: Facility age limit for growth percentiles is 20 years. Height/Length Change: Stable BMI (Calculated): 30.02 kg/m2 BMI for Age: Facility age limit for growth percentiles is 20 years. Mid Upper Arm Circumference (MUAC): Unable to Obtain Reason: Patient is 20 years old or older ([Date]) Prescribed Metabolic Formula & Diet: Limit portions of high protein foods Food/Nutrient Intake: PO/Oral: Breakfast: Bowl of apple cinnamon cereal + a little milk Morning snack: Chips Lunch: Turkey sandwich (1-2 slices) + chips, variety of breads Afternoon snack: Fruit sometimes, candy Dinner: Protein, starch, veggie (chicken, potatoe, broccoli, etc). Protein serving is smaller than the palm of [Gender] hand. Evening snack: Popcorn
Oral Fluids: Water, coffee, alcohol at night (10 drinks/week) Estimated Intake: Total Calories - kcal: Likely meeting needs due to stable weight Total Protein - grams: Reports ~60 g/day Significant Lab Values: I personally reviewed pertinent labs with citation of the following: [Date] Ammonia: 47 Plasma amino acids: wnl Vitamin D: 21.6 - recommend 2000 units daily Pertinent Medications and Supplements: Reviewed all current medications. L-citrulline 8g PO daily (taken in a.m.) Buphenyl 9 pills a.m. + 10 pills p.m. MVI: men?s one-a-day Vitamin D (1000 IU) Discontinued fish oil per cardiologists advice GI/GU Findings: none Adult Malnutrition Assessment Dietitian assessment of malnutrition: Findings do not support a diagnosis of malnutrition [Date] Primary indicators for malnutrition: Weight Loss - Moderate; N/A ([Date]), Weight Loss - Severe; N/A ([Date]), Intake - Moderate; N/A ([Date]) Muscle Grip St Signs: Lumba obviou well-de curves

Findings do not support a diagnosis of malnutrition Impaired Nutrient Utilization: unresolved Nutrition Intervention: Nutrition Prescription: Calorie Recommendation-kcal: 1712-2054 kcal Calorie Recommendation-kcal/kg: 19-23 kcal/kg Method for estimating calorie needs: Mifflin St. Jeor x 1-1.2 Protein Recommendation-grams: 45-91 g Protein Recommendation-g/kg: 0.5-1 g/kg Method for estimating PRO needs: Other (Comment) (Singh guidelines for urea cycle disorders) Fluid Recommended-mL: 1 mL/kcal Method for estimating needs: Holliday-Segar Method Vitamin/Mineral Recommendation: DRI Nutrition Interventions: Meals and Snacks: Continue to aim for ~60 g of protein from food per day. Continue to aim for a variety of foods from each food group while limiting portion sizes of protein. Try to incorporate fruits and vegetables into your diet. When choosing bread, all can fit into a healthy diet, but it can be helpful to look for whole grain or whole wheat. Sourdough is also a good option. Keep in mind that different breads may contain very different amounts of protein. Supplements: Continue multivitamin, vitamin D, 8g citrulline daily and 20 pills Buphenyl Collaboration and Referral of Nutrition Care: If you ever need surgery again or any further cancer treatment/ therapies, please let the genetics clinic know, so we can keep you safe during treatment. Obtain nutrition labs. We will let you know if any diet, supplement, or medication changes are necessary once the results come in. Consider a liver ultrasound. Collaboration of Care: Was [Name] referred to Birth-to-Three services at today?s visit? - No Was [Name]'s family referred to [Location] at today?s visit? - No Was [Name]?s family referred to a [Location] during today?s visit? - No Was [Name]'s plan to transition to adult health care providers and services (as appropriate) discussed today? - N/A Does [Name] have an ER protocol? - Yes Patient receives the following products from the [Location] None currently Samples provided in clinic today: none Monitoring/Evaluation: Indicator: Biochemical Data/ Medical Tests and Procedures; Criteria: Labs to be obtained within next month - ammonia, Vitamin D wnl, plasma amino acids: glutamine <120% upper cutoff, BCAAs low end of normal Follow up: RD will continue to follow patient., 1 year I spent 15 minutes in face-to-face care of this patient. [Provider], Registered Dietitian Electronically signed by [Provider], RD at [Date] 1:16 PM CDT

Truveta Language Model (TLM)


```
{
    "visit_date": "-",
    "signature_date": "[Date] 1:16 PM CDT",
    "diet": [
        {
            "name": "Limit portions of high protein foods",
            "reason": "-",
            "goal": "-",
            "consumed items": "apple cinammon cereal, milk, chips, turkey sandwich
            "avoided items": "-",
            "duration": "-",
            "status": "current",
            "route": "oral",
            "discontinuation reason": "-"
        }
    ],
    "intake": [
        {
            "name": "protein",
            "value": "60 g",
            "type": "Reported intake"
        },
        {
            "name": "calories",
            "value": "1712-2054 kcal",
            "type": "Recommendation"
        },
        {
            "name": "calorie",
            "value": "19-23 kcal/kg",
            "type": "Recommendation"
        },
        {
            "name": "protein",
            "value": "45-91 g",
            "type": "Recommendation"
        },
        {
            "name": "protein",
            "value": "0.5-1 g/kg",
            "type": "Recommendation"
        }
    ],
    "medication_supplement_formula": [
        {
            "name": "L-citrulline",
            "strength": "-",
            "dose schedule": "8g daily AM",
            "route": "PO",
            "status": "current"
        },
        {
            "name": "Buphenyl",
            "strength": "-",
            "dose schedule": "9 pills AM, 10 pills PM",
            "route": "-",
            "status": "current"
        },
        {
            "name": "MVI",
            "strength": "-",
            "dose schedule": "once daily",
            "route": "-",
            "status": "current"
        },
        {
            "name": "Vitamin D",
            "strength": "1000 IU",
            "dose schedule": "-",
            "route": "-",
            "status": "current"
        },
        {
            "name": "fish oil",
            "strength": "-",
            "dose schedule": "-",
            "route": "-",
            "status": "historical"
        }
```


TRUVETA moderna

All notes fully PHI redacted

Sample dietary data extracted shows depth of insight available

Protein and supplement intake: route, amount/dosage, and context

Formula

- *Anamix Junior powder*
- *1/3cup+1tsp Cyclinex 1, 7Tbsp ProPhree, 1/4cup Similac Advance powder; Abnormal GI tolerance related to O oral/ G-tube*

Enteral (tube)

- *Metabolic Formula; OTCD, multiple hospitalizations for MDE; Cyclinex, Neocate Junior Unflavored, Essential Amino Acid Mix, Polycal; Gtube*
- *Peptamen Jr (peptide based)/ Duocal (high cal, carb, protein-free) ; meet 75-100% assessed nutrient needs during admission, G-tube*

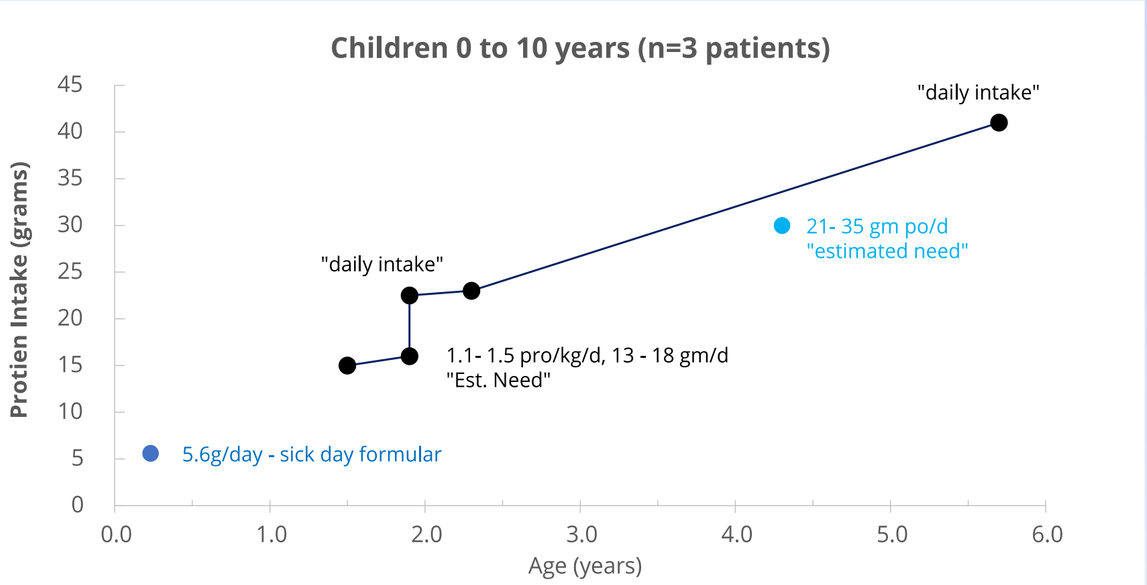
Oral

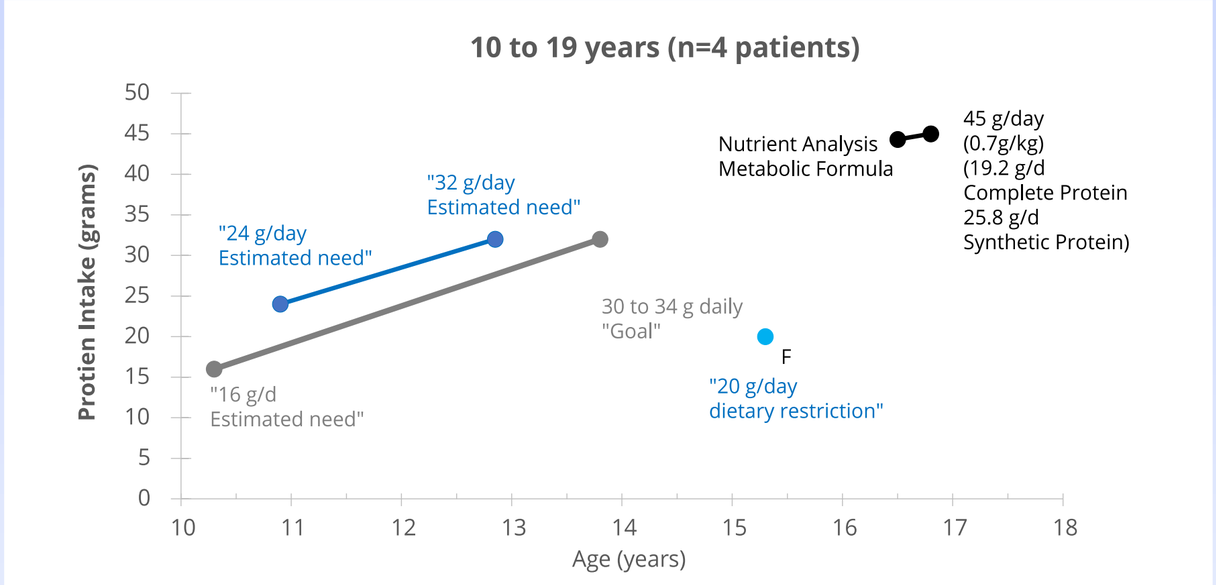
- *Low protein diet (30-35g/day); OTC deficiency; to provide adequate energy to prevent catabolism while limiting protein (nitrogen) intake to limit ammonia production*
- *Limit portions of high protein foods, ~60 g of protein from food per day; Late onset OTCD; Meet nutritional needs while managing symptoms*
- *Low protein diet; OTC deficiency; meet >75% of estimated kcal/protein*
- *Regular diet; OTC Deficiency; 25 g protein restriction*

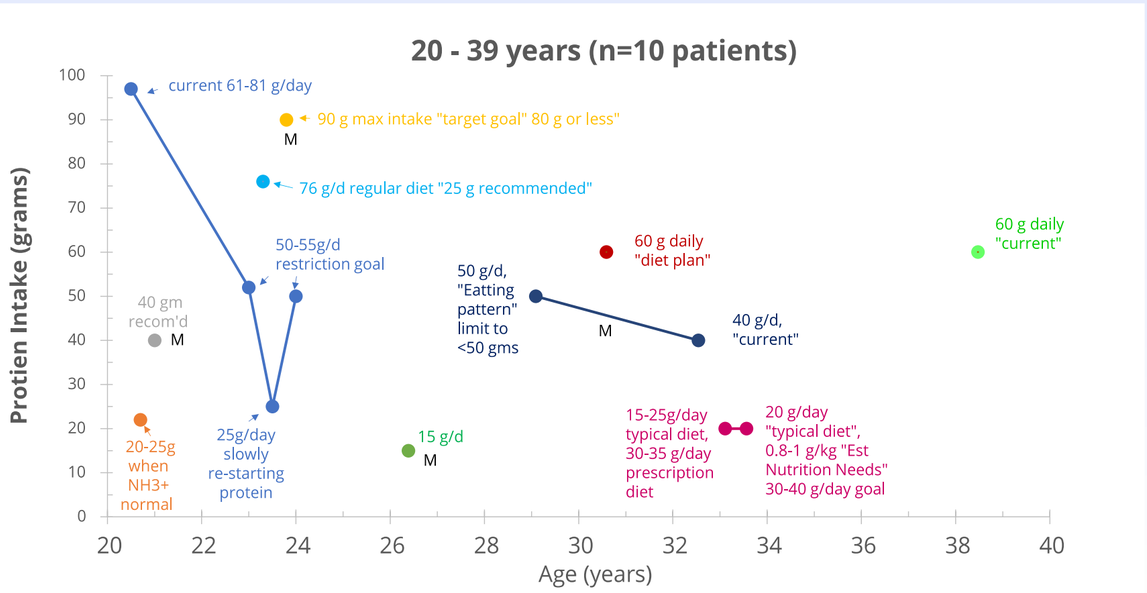
Supplements

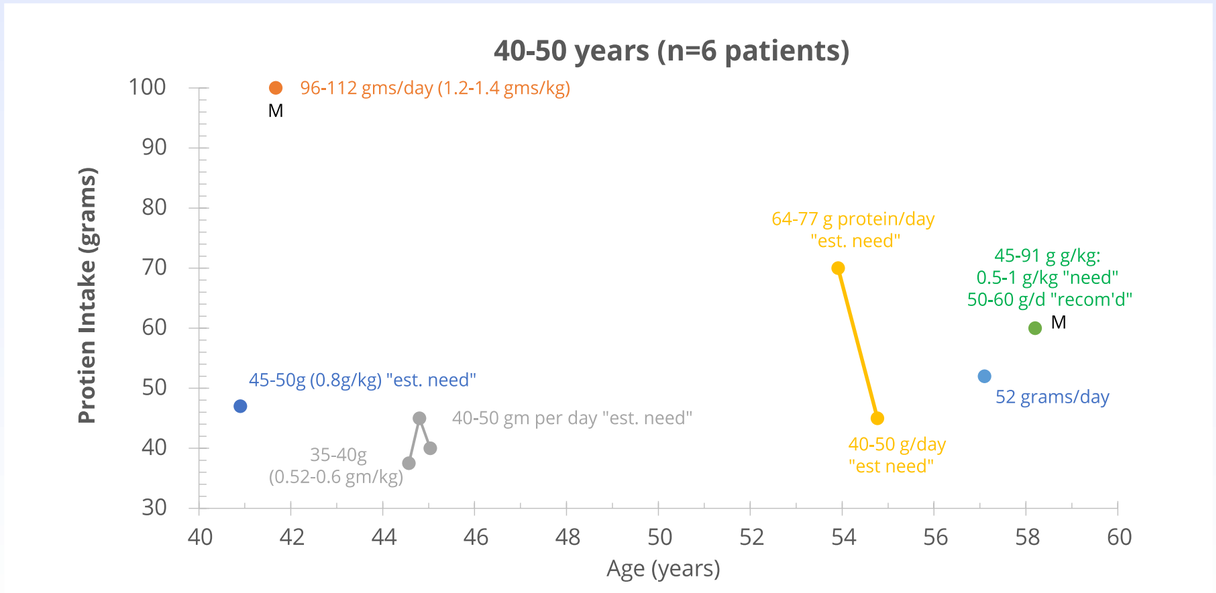
- *arginine (L-arginine) (R-GENE 10); 0.1; 5,880 mg Continuous; Intravenous*
- *Citrulline (CITRULLINE 1000); 1 g Pack; 5,000 mg 5 times daily; Gastric Tube*
- *Citrulline ; 200 mg PACK; 200 mg 3 times daily for 60 days; by mouth*
- *Citrulline; 1 g; Take 7 g daily; by mouth*
- *L-Citrulline ; 600 MG CAPS; 1,000 mg 2 times daily; oral*

Understanding protein intake by age group









Key research outcomes enabled

Established more complete understanding of OTCD

- Accurately identified patients with OTCD using SNOMED codes
- More accurately assessed burden of symptoms some that are underestimated

Extracted rich data on dietary patterns and variability

- Used AI to summarize detailed dietary notes, rather than doing manual chart reviews or prospective data collection to obtain that information
- Data will provide insight potential dietary confounders

Gained insights to inform trial design

- Enumerating events like HAEs and determining the rate of occurrence will inform trial size and the estimates of change needed to demonstrate treatment effectiveness
- Established context for disease burden and disease progression

Q&A

Scan this code to see
Truveta Studio in action

TRUVETA moderna


TRUVETA
Saving Lives with Data
Contact us info@truveta.com
Follow us @truveta