Design of a prospective, multinational registry to evaluate patients hospitalized with hyponatremia: the HN Registry

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Background: Hyponatremia is a prevalent condition in patients hospitalized across a broad range of conditions, including heart failure, cirrhosis, and the syndrome of inappropriate antidiuretic hormone (SIADH) secretion. Whether present on admission or developing during hospitalization, hyponatremia has been associated with increased mortality, longer hospital stays, and higher costs. Little is known, however, about its management and outcomes outside of clinical trial settings.

Methods: The Hyponatremia Registry (HN Registry) is a prospective, observational, multicenter, multinational study of patients hospitalized with either hypervolemic hyponatremia (cirrhosis and heart failure) in the United States or euvoemolic hyponatremia (SIADH) in both the United States and Europe. Study enrollment began in September 2010 at community, tertiary, and academic medical centers. Overall, the HN Registry is expected to enroll >5,000 patients with hyponatremia, at >280 sites. Data will be used to characterize demographic and clinical characteristics of patients hospitalized with hyponatremia, evaluate the comparative effectiveness of available treatment modalities, and document and compare length of hospital stay as a reflection of resource use associated with hospital management.

Discussion: Despite better understanding of the clinical consequences, economic impact, and prognostic significance of euvoemolic and hypervolemic hyponatremia, there remains a need to evaluate current “real-world” management. The HN Registry is designed to provide contemporary data on in-hospital evaluation, management, and length of stay in a large cohort of adult patients with hyponatremia. The HN Registry generated several design and analytical challenges that required unique approaches to facilitate collection of the most clinically relevant data.

Keywords: hypervolemia, euvoemolism, methodology, design, registry

Introduction

Hyponatremia, the most common electrolyte abnormality of hospitalized patients, has been associated with increased morbidity, mortality, and resource use, when present at hospital admission or acquired during hospitalization. The management of hyponatremia and its effect on outcomes in clinical practice are, however, poorly understood and have not been critically examined. Defined in many studies as a serum sodium concentration [Na+] <135 mmol/L, the precise frequency of hyponatremia depends on the serum [Na+] used as the cutoff, the patient population under study, and the clinical setting. Classification based on etiology and appropriate selection of therapeutic options requires an accurate determination of the underlying extracellular fluid volume status; data from small studies suggest that errors in the diagnosis of hyponatremia are common. However, evaluation of contemporary practice in an observational
registry (especially when the population under study is heterogeneous) is challenging, and issues encountered in the design and implementation of the Hyponatremia Registry (HN Registry) are discussed in this article.

Prevalence

The prevalence of hyponatremia depends on the threshold serum [Na⁺] value selected and the associated disease states and location (eg, acute care facility or outpatient setting) of the population included in the analysis. For example, in a prospective cohort of 98,411 hospitalized adults, a serum [Na⁺] <135 mmol/L was found at admission in 14.5% of patients and developed during hospitalization in an additional 5.2%. Other studies have found hyponatremia at admission in up to 30% of patients. When more restrictive definitions of hyponatremia are used, the frequency is lower: -0.5%–2.5% of patients have [Na⁺] concentrations <125 mmol/L. The occurrence of hyponatremia is higher in older than in younger individuals, likely due in part, to the increased frequency of comorbid conditions, use of medications associated with hyponatremia, and an idiopathic form of the syndrome of inappropriate antidiuretic hormone secretion (SIADH) found in elderly patients.

Prognostic implications

In a large retrospective, multicenter study, the presence of a serum [Na⁺] <135 mmol/L at hospital admission was independently associated with increased in-hospital mortality and intensive care unit (ICU) admission, of 55% and 60%, respectively. Hyponatremia was also associated with a 1-day increase in average hospital length of stay (LOS) and an average increase of $2,289 (in 2005 USD) in total costs/patient. In other large cohorts, risk of in-hospital mortality, likelihood of ICU admission, hospital LOS, and total costs increased in association with decreasing serum [Na⁺]. These adverse outcomes were more frequent even when serum [Na⁺] was in the range of 130–134 mmol/L. Furthermore, worsening of hyponatremia during hospitalization is associated with increased adjusted odds of in-hospital mortality and discharge to short- or long-term care facilities.

Treatment

The treatment of hyponatremia is based on the presence and severity of symptoms, the extracellular volume status of the patient, and whether the onset of hyponatremia was acute (<48 hours) or chronic (≥48 hours). Fluid restriction is typically used in less symptomatic cases of euvolemic and hypervolemic hyponatremia; if fluid intake is reduced to a level below the sum of insensible losses and any renal electrolyte-free water excretion, negative water balance will ensue. The degree of water restriction required to increase serum [Na⁺] depends on the magnitude of the renal diluting impairment, but restriction to ≤1000 mL/d is often necessary. From a practical perspective, significant water restriction is difficult to initiate and maintain over long periods and may be relatively ineffective. In general, the success rate for fluid restriction decreases with higher urine osmolality and reduced electrolyte-free water clearance, which reflect higher arginine vasopressin (AVP) concentrations.

Several drugs have traditionally been used after failure of fluid restriction, including demeclocycline, urea, and lithium. None of these treatments is approved by the US Food and Drug Administration for use in hyponatremia, and each has limitations. Ultrafiltration has been suggested as an option for treatment of hyponatremia in patients with congestive heart failure, but this approach extracts isotonic fluid from blood, does not directly improve serum [Na⁺], and is not approved for the treatment of hyponatremia.

The vasopressin receptor antagonists, or “vaptans,” are the newest pharmacologic option for euvolemic or hypervolemic hyponatremia. These agents block the actions of AVP at vasopressin V₁ receptors in cells of the renal collecting duct and provide a targeted approach to treatment in patients whose hyponatremia is caused by inappropriately elevated AVP concentrations. Conivaptan (Astellas Pharma Inc, Tokyo, Japan) is a dual V₁/V₂-receptor antagonist that is available for intravenous use; tolvaptan (Otsuka Pharmaceutical Co, Naruto, Japan) is a selective V₂-receptor antagonist that is taken orally once daily and may be continued following hospital discharge.

Given these varying approaches and lack of national guidelines, the multinational observational HN Registry has been designed to provide insight into contemporary practice and clinical response to medical interventions across most euvolemic and hypervolemic hyponatremic patients. The data collected from the HN Registry will provide important analyses of the contemporary use of various diagnostic and therapeutic approaches, including duration of therapy, effect on serum [Na⁺], and impact on LOS.

HN registry methods

The HN Registry (ClinicalTrials.gov Identifier: NCT01240668) is a prospective, observational, multicenter study of patients hospitalized with euvolemic or hypervolemic hyponatremia in the United States and with hyponatremia...
secondary to SIADH in seven European countries (Denmark, France, Germany, Italy, Spain, Sweden, and the United Kingdom). The HN Registry was designed to provide “real-world” data on patients with serum \([Na^+] \leq 130\) mmol/L, excluding patients with hypovolemic hyponatremia. Although hyponatremia is commonly defined as a serum \([Na^+] < 135\) mmol/L, a cut-off value of \(\leq 130\) mmol/L was chosen to select patients with increased risk for clinical symptoms of hyponatremia and greater likelihood of receiving therapies intended to correct low serum \([Na^+]\).

The specific, predefined objectives of the HN Registry are to: (1) obtain demographic and clinical characteristics of patients with euvolemic or hypervolemic hyponatremia in the hospital setting; (2) evaluate the effectiveness of prescribed treatment modalities in these patients; and (3) define and compare LOS as a surrogate for resource usage associated with hospital management.

Patients are identified by study personnel based on serum \([Na^+]\); criteria have been established to minimize the likelihood of inclusion of patients with hypovolemic hyponatremia. Following an extensive training session, site study coordinators extract data from the inpatient medical record, starting with hospital admission and continuing through discharge. The data are entered in a case report form or electronic data capture system. Because this is an observational registry, both diagnosis and treatment are determined by the patient’s treating physicians and not by HN Registry investigators.

The study is being conducted in compliance with all national and local regulatory requirements. The study protocol must be approved by the institutional review board or independent ethics committee at each hospital, before patient enrollment is initiated. In Europe, as required, the approval of the appropriate national and/or regional regulatory bodies was also obtained. When a waiver of consent is not granted by the appropriate ethics committee, individual informed patient consent is obtained prior to data collection.

Study enrollment began in September 2010 at community, tertiary, and academic medical centers, with expected enrollment of 5,000 patients, from >280 institutions. The clinical research organization providing support is REGISTRAT-MAPI (Lyon, France). Funding is provided by Otsuka America Pharmaceutical, Inc (Rockville, MD, USA).

### Inclusion and exclusion criteria

The inclusion and exclusion criteria are shown in Table 1. Briefly, hospitalized adults aged \(\geq 18\) years are eligible if they have euvolemic (United States and Europe) or hypervolemic (United States only) hyponatremia characterized by a serum \([Na^+] \leq 130\) mmol/L either on admission or developing during their hospital stay. The chart-based diagnosis of euvolemic requires the absence of clinical or historical evidence of extracellular fluid volume expansion or depletion, including the absence of edema and ascites, or a physician’s written diagnosis of SIADH. In addition, the urine \([Na^+]\) should not be \(< 20\) mmol/L (if measured), and the blood urea nitrogen (BUN):creatinine ratio should not be \(> 20\) in patients listed as euvolemic. Hypervolemia is defined as excess extracellular fluid volume manifesting as dependent edema or ascites in the presence of \(\geq 1\) comorbid condition of congestive heart failure, cirrhosis, liver failure, or nephrotic syndrome.

Key exclusion criteria include hypovolemic hyponatremia and random blood glucose \(> 250\) mg/dL, or \(180–250\) mg/dL together with serum \([Na^+]\) of \(127–130\) mmol/L at entry. Patients receiving renal replacement therapy for either chronic kidney disease or acute kidney injury are also excluded. Patients may not be enrolled if they are simultaneously receiving an investigational drug or other agent in a clinical trial setting.

### Data collection

Data collected on hospital admission include date of hospitalization, admitting diagnosis, demographics (age, sex,
and in the United States only, race), details on the underlying condition (including left-ventricular ejection fraction and New York Heart Association classification for heart failure, \textsuperscript{35} Child-Pugh classification \textsuperscript{36} and Model for End-Stage Liver Disease score for cirrhosis, \textsuperscript{37} and underlying etiology for SIADH), history of hyponatremia (including number of prior hospitalizations in the past year and acuity of onset of hyponatremia, when available), medications at hospital admission (including those prescribed to treat hyponatremia, natriuretic diuretics, and hyponatremia-inducing drugs), and vital signs at admission and on the day hyponatremia was first documented.

Additional data are collected from the patient’s medical record on each day of hospitalization, including body weight, signs and symptoms potentially associated with hyponatremia, serum [Na\textsuperscript{+}], and other standard laboratory tests, such as serum electrolytes. If obtained, results of other relevant laboratory tests will be recorded, including urinary electrolytes, urinary creatinine and urea nitrogen, serum and urine osmolality, thyroid-stimulating hormone, cortisol, results of a cosyntropin stimulation test, and heart failure biomarkers (ie, B-type natriuretic peptide and N-terminal pro-B-type natriuretic peptide). Documentation also includes volume of fluid intake and output over each 24-hour period (if available); information on the amount and duration of fluid restriction, including days on which adjustments in the degree of fluid restriction are made; details pertaining to treatment with intravenous saline, including type (hypertonic 2\%–3\% or isotonic 0.9\% solution); medications used to treat hyponatremia; natriuretic diuretics and other hyponatremia-inducing drugs; procedures used to manage comorbidities; specialty of the physician responsible for the patient’s management during the hospital stay and use of subspecialty consultations; and hospital LOS, including LOS in ICU and intermediate care unit. At the time of hospital discharge, data capture includes discharge medications and disposition.

Endpoints and endpoint adjudication
The analysis of study endpoints is descriptive and associative, consistent with the observational design of the study. The HN Registry has two primary endpoints: change in serum [Na\textsuperscript{+}] from the beginning to the end of the treatment period or hospital discharge and hospital LOS from time of first presentation of hyponatremia (day of admission or subsequently) to discharge.

Secondary endpoints include the effectiveness of individual therapies, alone and in combination, for correction of hyponatremia, and time needed to achieve correction, as well as the effectiveness of individual therapies in achieving symptom improvement. Given the inability of a registry-based study to impose a standardized protocol on treating physicians or mandate achievement of a particular treatment goal, we prespecified several broad definitions of correction: achievement of a serum [Na\textsuperscript{+}] >130 mmol/L, a serum [Na\textsuperscript{+}] ≥135 mmol/L, and/or an increase in serum [Na\textsuperscript{+}] by ≥5 mmol/L. If the serum [Na\textsuperscript{+}] initially corrects to a value >130 mmol/L but subsequently falls below that threshold, this new “episode” is analyzed as a separate case-based event.

Secondary resource usage endpoints include medically necessary LOS in hospital and specialized hospital units, and impact of hyponatremia on ICU and overall hospital LOS. The study is also designed to evaluate several descriptive secondary endpoints, including the relative proportions of underlying etiologies of hyponatremia, the investigations performed to diagnose hyponatremia, and time to treatment initiation and type of therapies used to treat hyponatremia.

Cases that do not appear to meet inclusion, exclusion, or secondary criteria (Table 2), based on initial evaluation by the HN Registry project manager, are reviewed in a separate adjudication process performed independently by ≥2 physician members of the HN Registry Steering Committee. This mechanism was established to ensure that inclusion and exclusion criteria are satisfied; patients who fail to meet eligibility criteria will be considered as screen failures and will be dropped from the analysis (see Steering Committee participation).

In addition, multiple means of analyzing LOS data will be used to mitigate the challenge of confounders, such as

**Table 2** Criteria used to refer patients for adjudication

| 1. | <24 hours of serum [Na\textsuperscript{+}] ≥130 mmol/L |
| 2. | Correction of serum [Na\textsuperscript{+}] (>130 mmol/L) after administration of isotonic saline as principal therapy |
| 3. | Random blood glucose >250 mg/dL, or between 180 and 250 mg/dL with serum [Na\textsuperscript{+}] of 127–130 mmol/L |
| 4. | Patients receiving renal replacement therapy |
| 5. | Urine [Na\textsuperscript{+}] <20 mmol/L in ostensibly euvolemic patients |
| 6. | Patients presenting with cerebral salt wasting |
| 7. | BUN:creatinine ratio >20 for euvolemic and >40 for hypervolemic patients |
| 8. | Diagnosis of heart failure and euvolemia |
| 9. | Diagnosis of cirrhosis and euvolemia |
| 10. | Diagnosis of nephrotic syndrome and euvolemia |
| 11. | Diagnosis of SIADH and hypervolemia |
| 12. | Diagnosis of hypervolemia or euvolemia, but no comorbidity or etiology described |

**Abbreviations:** BUN, blood urea nitrogen; [Na\textsuperscript{+}], sodium concentration; SIADH, syndrome of inappropriate antidiuretic hormone.
severity of patient illness or prolonged LOS due to non-
medical reasons (see Design challenges).

Steering Committee participation
The seven-member Steering Committee comprising two
cardiologists, a nephrologist, an endocrinologist, a hos-
pitalist, a hepatologist, and a pharmacist was formed and
chartered to develop the protocol, advise on scientific and
logistical issues, and monitor the progress of enrollment.
In addition, physician Steering Committee members engage in a formal adjudication process for the subset of
cases that appear on initial screening to require additional
scrutiny before inclusion in the HN Registry database.
Excluded cases include those in which the serum [Na]

 \[ \text{was } \leq 130 \text{ mmol/L for a duration } < 24 \text{ hours and when the} \]

 \[ \text{diagnosis of heart failure or cirrhosis was accompanied by} \]

 \[ \text{the diagnosis of euvolemia.} \]

The sponsor plays a collaborative role, but the Steering
Committee supervises the formal adjudication process and
makes final decisions about patient inclusion.

Design challenges
The present investigation, subject to the inherent limitations
of any registry, presented a number of design challenges that
had to be overcome (Table 3).

Ideally, a registry should enroll consecutive patients.
Doing so permits accrual of data about prevalence of vari-
ous etiologies of hyponatremia and eliminates selection bias.
However, for hyponatremia, consecutive enrollment would
require ascertainment by screening all cases identified by the
laboratory, with serum [Na]

 \[ \text{below the inclusion threshold. Because we were interested in tracking management methods} \]

 \[ \text{employed by a variety of specialists, the roster of investiga-
}

 tors was not limited to endocrinologists and nephrologists
to whom unselected hyponatremia cases might be referred.

Rather, we also recruited cardiologists and hepatologists,
whose practice and patient accrual are likely limited to
patients with primary disorders within their specialty. This
choice means we can report the distribution of etiologies
among enrolled patients but not the distribution among
unselected hyponatremic patients in general. However, we
did encourage investigators to enroll consecutive patients, as
a means of minimizing bias.

The customary definition of SIADH is euvolemic
hypotonic hyponatremia occurring due to water retention
induced by persistent secretion of vasopressin not fully sup-
pressed despite hypotonicity. Patients must be euvolemic
by conventional clinical assessment, with no evidence of
volume depletion and no edema. Confirmatory laboratory
criteria include a documented low serum osmolality with
non-maximally dilute urine and normal thyroid and adre-
nal function. In the HN Registry, no specific protocol for
diagnosis of hypervolemic or euvolemic hyponatremia was
imposed on the study centers because the major goal was
to determine which diagnostic tests and procedures were
chosen by clinicians as they managed hyponatremia. In the
absence of a standardized evaluation, one of the prevalent
limitations identified during the early phases of data collec-
tion was the frequent lack of sufficient detail in the medi-
cal record to categorize volume status and determine the
precise etiology of hyponatremia. We addressed this issue
by abstracting urine sodium concentration, BUN:creatinine
ratio, and response to normal saline infusion, if present
in the medical record, to confirm or refute the absence
of volume depletion. Correction of hyponatremia after
normal saline infusion suggests that volume depletion was
present and was the cause of the hyponatremia. Patients
classified as having euvoletic hyponatremia who had a
BUN:creatinine ratio > 20:1, a urine sodium < 20 mmol/L,
or whose hyponatremia was corrected solely by administra-
tion of isotonic saline infusion were referred for adjudica-
tion to confirm that the diagnosis of euvoletic was correct.
In addition, no specific goal for posttreatment serum [Na]
can be imposed in the real-world setting. The serum [Na]
achieved before a patient is deemed by the treating physi-
cians to be stable enough for discharge is expected to vary
with baseline serum [Na] and status of the underlying
disease. As a result, the three separate definitions of cor-
rection (vide supra) were designated.

Further, because some patients receive multiple and
temporally overlapping therapies that could impact serum
[Na], attributing response to a single intervention may be
difficult. An intention-to-treat approach was considered, but

### Table 3 Challenges in the design of the HN Registry

| 1. Development of criteria for hypovolemia, euvolemia, and hypervolemia |
| 2. Definition of “correction” of serum [Na] |
| 3. Definition of a new “episode” of hyponatremia if serum [Na] initially corrects, but subsequently redevelops later in hospitalization |
| 4. Accounting for confounders that impact LOS |
| 5. Developing various LOS calculations based on time of identification and treatment of hyponatremia |
| 6. Identifying symptoms attributed to hyponatremia and their improvement based on documentation in medical record |
| 7. Developing strategies to identify patients for enrollment |
| 8. Avoidance of selection bias in an observational study design |

**Abbreviations:** HN, hyponatremia; LOS, length of stay; [Na], sodium concentration.
fluid restriction is frequently used and often the first-line treatment for hyponatremia, such that the potential impact of second- and third-line therapies used sequentially would not be apparent. We chose to describe which approaches are taken and when, and to monitor the overall rate of correction (or lack thereof) in serum [Na\(^+\)]. By extension, another limitation of the HN Registry design is that the order and choice of therapies was at the discretion of the treating clinician rather than stipulated by an experimental plan. A preliminary list of the many treatment maneuvers used in the HN Registry, based on an analysis of the first 500 adjudicated cases, is shown in Table 4. The list includes treatment regimens that were identified in \(\geq1\%\) of the treatment events. Multiple episodes of hyponatremia may occur during a single patient's hospitalization and, therefore, some patients may be counted more than once. The analytical plan calls for examination of both sequential treatments (patients who receive \(\geq2\) non-overlapping therapies) and combination treatments (patients who receive \(\geq2\) therapies together during a given treatment period).

We limited evaluation of resource utilization to LOS, in part because the collection of hospital bills would mandate informed consent. Nevertheless, it will be difficult to control for confounders such as comorbidities, severity of illness, and nonmedical factors like bed availability at skilled nursing facilities. The absence of reliable and systematic evaluation and documentation of patient symptoms associated with hyponatremia and their subsequent improvement present additional challenges; for example, the attribution of symptoms to hyponatremia may be confounded by coexisting hepatic encephalopathy in cirrhosis or low cardiac output syndrome in heart failure.

**Table 4** Treatment maneuvers used in the HN Registry

<table>
<thead>
<tr>
<th>Therapy</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid restriction</td>
<td>335 (34.1)</td>
</tr>
<tr>
<td>Normal saline</td>
<td>115 (11.7)</td>
</tr>
<tr>
<td>Fluid restriction and normal saline</td>
<td>92 (9.4)</td>
</tr>
<tr>
<td>Fluid restriction and tolvaptan</td>
<td>80 (8.1)</td>
</tr>
<tr>
<td>Fluid restriction and other therapy</td>
<td>64 (6.5)</td>
</tr>
<tr>
<td>Tolvaptan(^a)</td>
<td>62 (6.3)</td>
</tr>
<tr>
<td>Other therapy(^a)</td>
<td>41 (4.2)</td>
</tr>
<tr>
<td>Fluid restriction and hypertonic saline</td>
<td>30 (3.1)</td>
</tr>
<tr>
<td>Fluid restriction, normal saline, and other therapy(^a)</td>
<td>22 (2.2)</td>
</tr>
<tr>
<td>Hypertonic saline</td>
<td>19 (1.9)</td>
</tr>
<tr>
<td>Fluid restriction, normal saline, and tolvaptan</td>
<td>14 (1.4)</td>
</tr>
<tr>
<td>Normal saline and other therapy(^a)</td>
<td>11 (1.1)</td>
</tr>
<tr>
<td>Fluid restriction, normal and hypertonic saline</td>
<td>10 (1.0)</td>
</tr>
</tbody>
</table>

**Notes:**\(^a\)Urea, salt tablets, demeclocycline; \(^c\)<1% of patients received conivaptan. **Abbreviation:** HN, hyponatremia.

**Preliminary insights**

A rigorous process of data collection, quality control, and data “scrubbing” has been completed for the first 500 patients in the HN Registry. Preliminary data are shown in Table 5. The mean age is higher than in most randomized controlled trials involving hyponatremia, and LOS is long, consistent with the severity and in most cases, chronicity of the underlying medical diagnoses. Furthermore, the majority of patients within the HN Registry were treated by either hospitalists or internists. Subspecialists, primarily nephrologists and endocrinologists, were consulted for hyponatremia in 211 patients (42.2%).

**Discussion**

Observational registries can be powerful tools to document the course of disease and variations in treatment and outcomes, and provide valuable insights about real-world medical practice. In particular, registries can provide information regarding the clinical context when multiple or complex therapies are administered and can also generate hypotheses for further study that may not be obtained from randomized controlled trials.\(^38\) The utility and applicability of registry data, however, rely heavily on the quality of the data obtained and, in particular, the inclusion and exclusion criteria used to define the patient population under study. Because of the nature of their design, randomized controlled trials minimize selection bias to allow comparison between treated and nontreated patients; however, they do not provide information on real-world practice.

The HN Registry, the first study to provide an in-depth understanding of contemporary real-world management practices for euvoletic or hypervolemic hyponatremia, incorporates a rigorous process to define inclusion and exclusion of cases, and thus will allow an evaluation of patient
outcomes and current resource usage. Careful consideration was given to the design of the HN Registry, the quality of the collected data, and the analytical approach. Close collaboration between Steering Committee members, statisticians, and study coordinators involved in the development and management of the HN Registry will be instrumental in ensuring quality of the collected data. Preliminary data suggest that a large number of treatment regimens are currently being used by physicians to manage hyponatremia. Ultimately, information from the HN Registry may help to define and refine optimal care for patients hospitalized with hyponatremia or who develop hyponatremia during hospitalization.

Acknowledgment
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Disclosure
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