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Data Warehousing
Planning & Design

Michael Commo
Technical Consultant
Michael.Commo@GalenHealthcare.com

Data Warehousing Agenda

- **Overview**
  - Benefits to Warehousing
  - Defining an Approach
  - Define Key Terms

- **Example**
  - Planning to Warehouse
  - Designing a Warehouse
  - Loading the Warehouse
  - Reporting from the Warehouse

Scope

- **Investigate data warehousing, and its applicability to the healthcare industry.**
- **Identify problems that data warehouses can be designed to solve.**
- **Build a data warehouse from a simplified EHR data model.**
- **Disclaimer: This presentation**
  - will be technical
  - was designed to be applicable to a broad audience
  - will utilize an over-simplified, contrived example

Poll Question 1

Data Warehousing

OVERVIEW

What is Data Warehouse?

- **A database**
  - Used for reporting / data analytics.
  - Central repository for data
  - Created by integrating data from one or more disparate sources.

- **Warehouse as a base**
  - Executive dashboards
  - Auditing tools
  - Marketing analysis tools

- **ETL describes the process of loading a data warehouse:**
  - E: Extract data from outside sources
  - T: Transform (cleanse, normalize, translate) data to fit operational needs
  - L: Load data into the target database

Key Data Warehousing Terms:

- **Aggregation: Values of multiple rows are grouped together as input on certain criteria to form a single value of more significant meaning**
  - *Examples*: Average, Count, Maximum, Minimum, Sum, etc.
- **Normalization: The process of organizing the fields and tables of a relational database to minimize redundancy and dependency.**
  - Divide large table(s) into smaller (and less redundant) tables
  - Define relationships between these tables
  - De-normalize: purposefully don't do or undo this work for performance or other reasons
- **Contention: Database resource (row/table/page) locking resulting from one operation inhibits a second, concurrent, operation from completing, at least until the first operation is successful.**
  - Deadlock occurs when contention for resources cannot be resolved

EHR Data Models

- **EHR databases were designed for transaction processing**
  - Designed to meet the EHR application's needs
  - Not designed for reporting

- **Don't be intimidated by EHR data volume**
  - Many of our clients have very large EHR databases
  - Collapse/summarize data before storage
    - Save space
    - Enable faster reporting

Benefits of Implementing a Data Warehouse

Business Reasons:

- Enable high-level (aggregate/summmarized) reporting
- Enable ad-hoc (custom, end user) reporting
- Integrate data from multiple sources (multiple EHRs or EHR+PM)
- Improve data quality

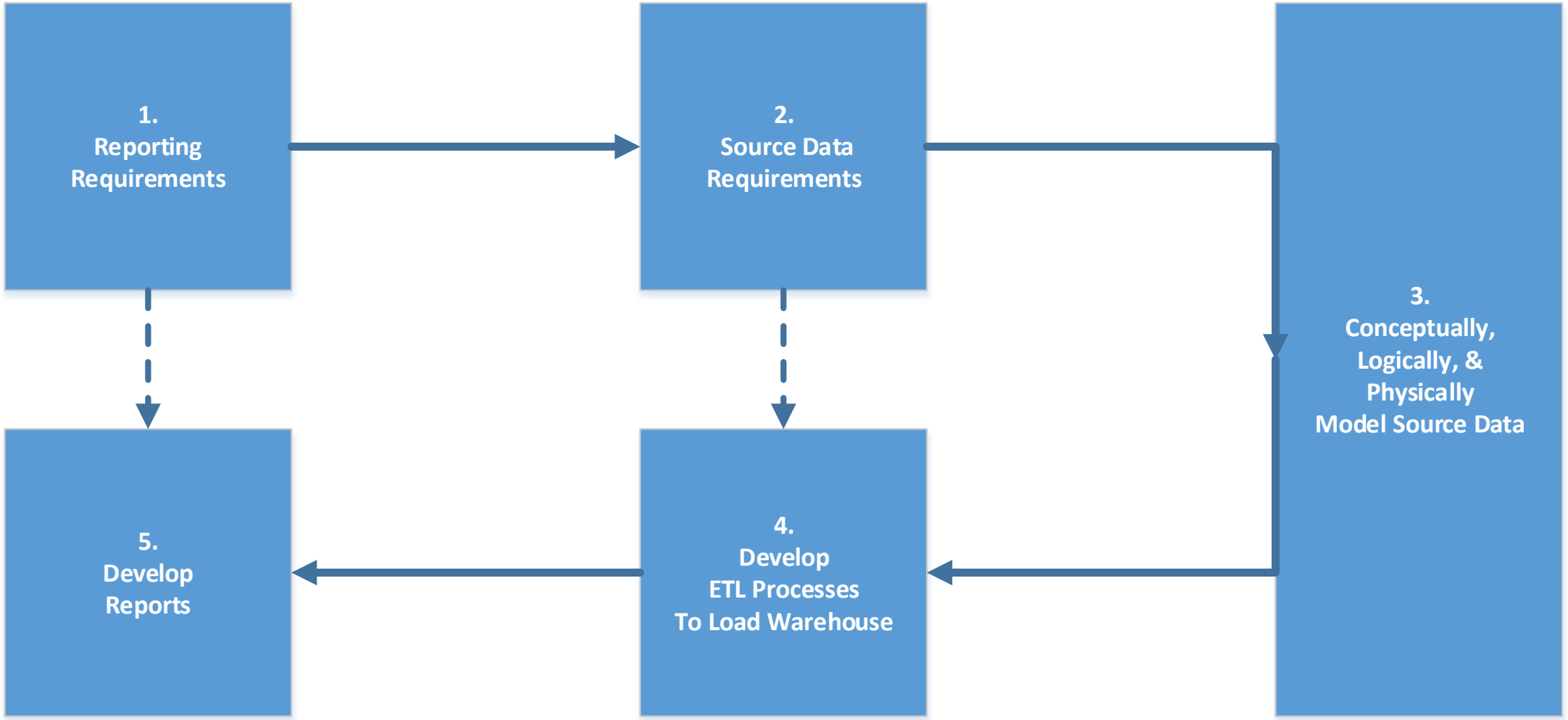
Technical Reasons:

- Archival of data
- Maintain historic views of operational data
- Restructure data to make sense for business users (enable ad-hoc reporting)
- Restructure data model for performance, without impacting operational systems
- Alleviate contention – don’t use live transaction processing systems for analytics

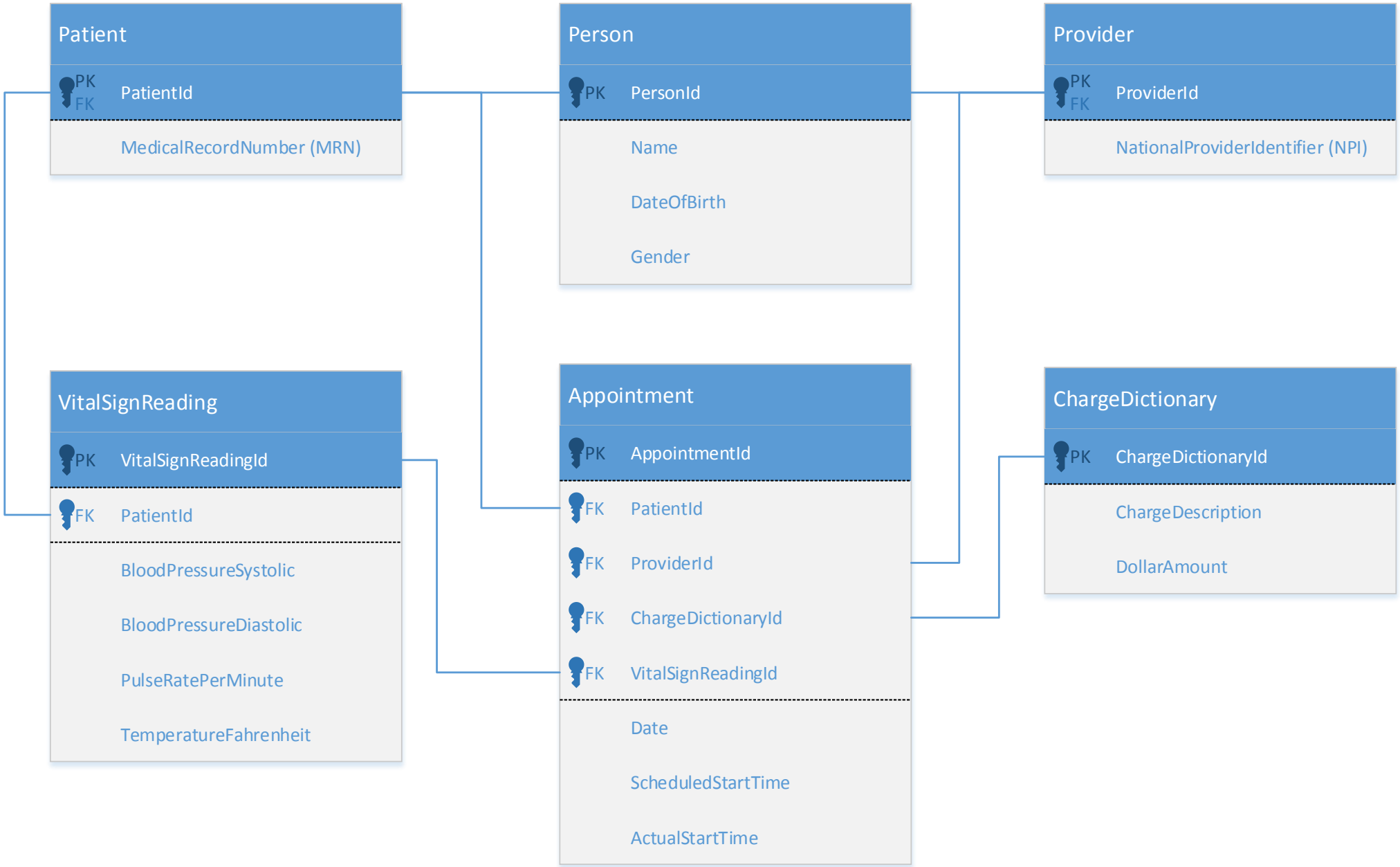
A Step-by-Step Approach to Warehousing

- **Present the approach**
- **Define a simple Electronic Health Record (EHR) operational data model**
- **Ask questions the model doesn't answer directly**
  - Assume aggregation would have performance implications for EHR users
  - Assume contention/deadlock are not acceptable in operational environment
- **Build a data warehouse to answer these questions**
  - Model warehouse
  - Load warehouse
  - Template reports off the warehouse

Step-by-Step Approach to Data Warehousing (Diagram)

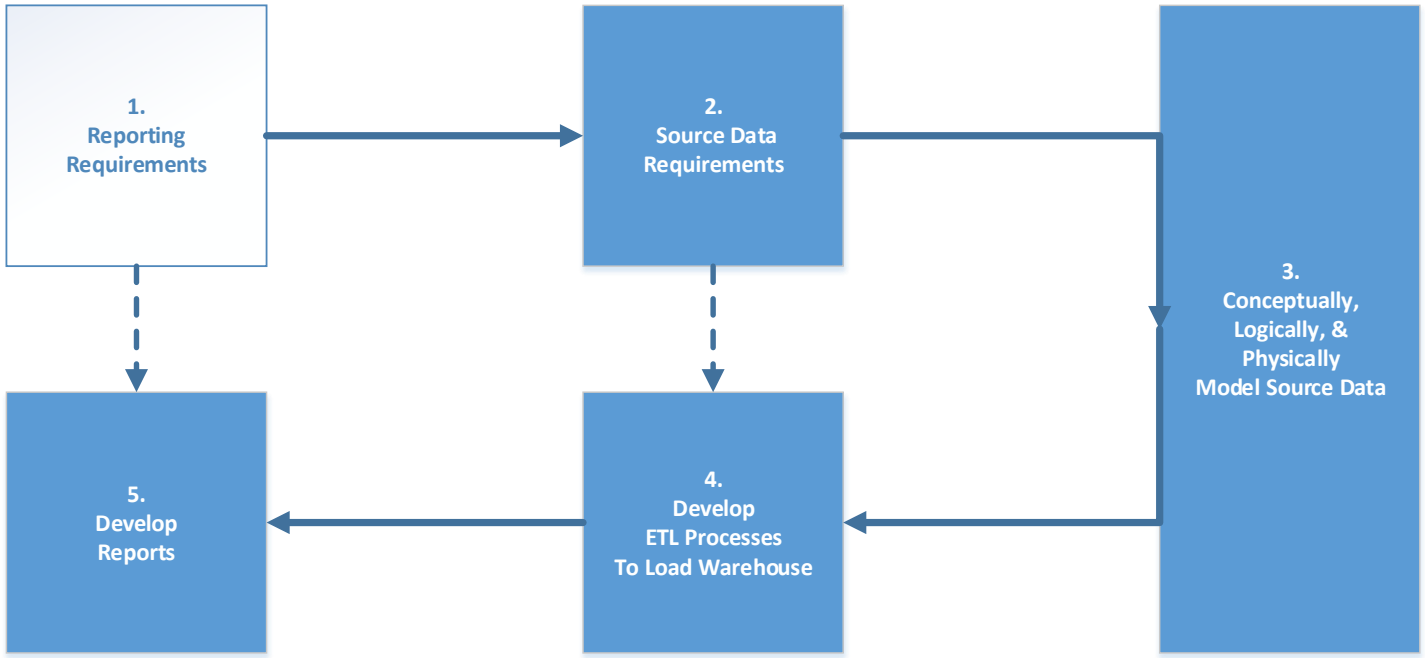


EHR Data Model



Data Warehousing

PRACTICE



REPORTING REQUIREMENTS

Reporting Requirements

- **Assume the following questions have recently been asked:**
  - Which patients have seen a rise in both their average blood pressure, and average pulse rate, since last year?
  - Which providers are habitually late to appointments?
  - Enable top performer awards – determine total revenue, per provider, per year.
  - Determine advertising campaign target audience:
    - Which gender provided more revenue last year?
      - Were these patients generally under or over 50 years of age?

Reporting Requirements

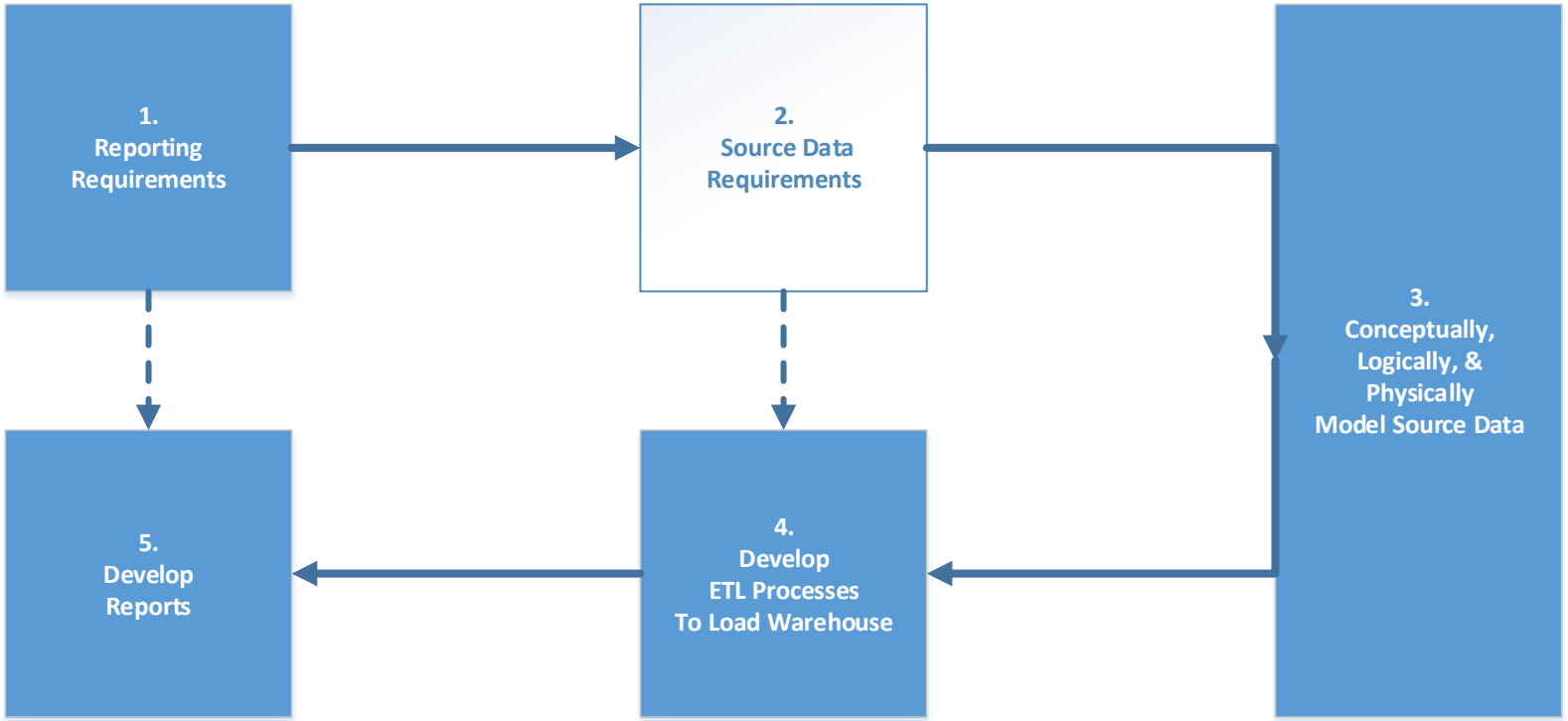
- **The data exists in the EHR data model to answer these questions**
  - Reporting against the EHR model would be very inefficient
  - Aggregation could cause performance implications for EHR users
    - Overall system latency
    - Errors attempting to update/save patient information
    - Inability to view vital patient information

- **Solution:**
  - Decide to develop a data warehouse to fulfill these reporting requirements
  - Reporting requirements defined
    - next step is to identify the data necessary to fulfill these requirements

Poll Question 2

Data Warehousing

PRACTICE



SOURCE DATA REQUIREMENTS

Data Requirements

- **Associated Reporting Requirement:**
  - Which patients have seen a rise in both their average blood pressure, and average pulse rate, since last year?

- **Necessary Source Data Element(s):**
  - *Patient* and *Person* demographic information
  - *VitalSignReading* metrics
    - BloodPressureSystolic
    - BloodPressureDiastolic
    - PulseRatePerMinute
  - *Appointment*: just to get the *Appointment* date of the *VitalSignReading*

Data Requirements

- **Associated Reporting Requirement:**
  - Which providers are habitually late to appointments?

- **Necessary Source Data Element(s):**
  - *Provider* demographic information
  - *Appointment* Information:
    - ScheduledStartTime
    - ActualStartTime

- **Unnecessary Source Data:**
  - There was a patient who had to wait
  - Bring over the associated *Patient* just in case we want to report on it in the future

Data Requirements

- **Associated Reporting Requirement:**
  - Enable top performer awards – determine total revenue, per provider, per year.

- **Necessary Source Data Element(s):**
  - *Provider* and *Person* demographic information
  - *Appointment*:
    - Get date of the charge
    - Reference the associated charge
  - Get *ChargeDictionary DollarAmounts* for all referenced Charges

Data Requirements

- **Associated Reporting Requirement:**
  - Determine advertising campaign target audience:
    - Which gender provided more revenue last year?
    - Were these patients generally under or over 50 years of age?

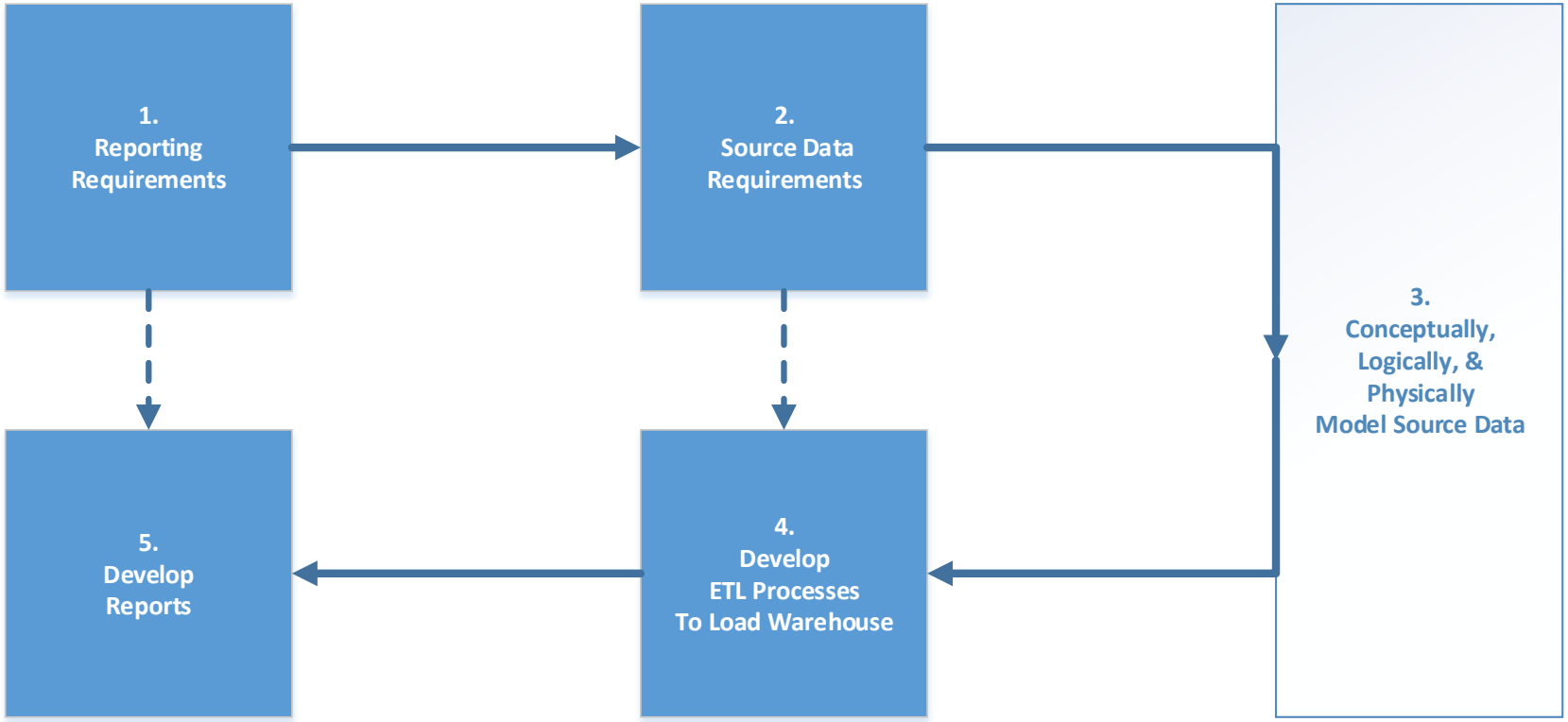
- **Necessary Source Data Element(s):**
  - *Patient* and *Person* demographic information (age and gender)
  - *Appointment*:
    - *Get date to determine year*
    - Get the associated *charge*
  - Get *ChargeDictionary DollarAmounts* for all referenced Charges

Data Requirements (Combined)

- **Necessary source data elements for all reporting requirements:**
  - *Patient, Provider* and *Person* demographic information
  - *Appointment*:
    - Date of the VitalSignReading
    - ScheduledStartTime and ActualStartTime (or just the difference between them)
    - Date of the Charge
  - Get *ChargeDictionary DollarAmounts* for all referenced Charges
  - *VitalSignReading* metrics
    - BloodPressureSystolic
    - BloodPressureDiastolic
    - PulseRatePerMinute

Data Warehousing

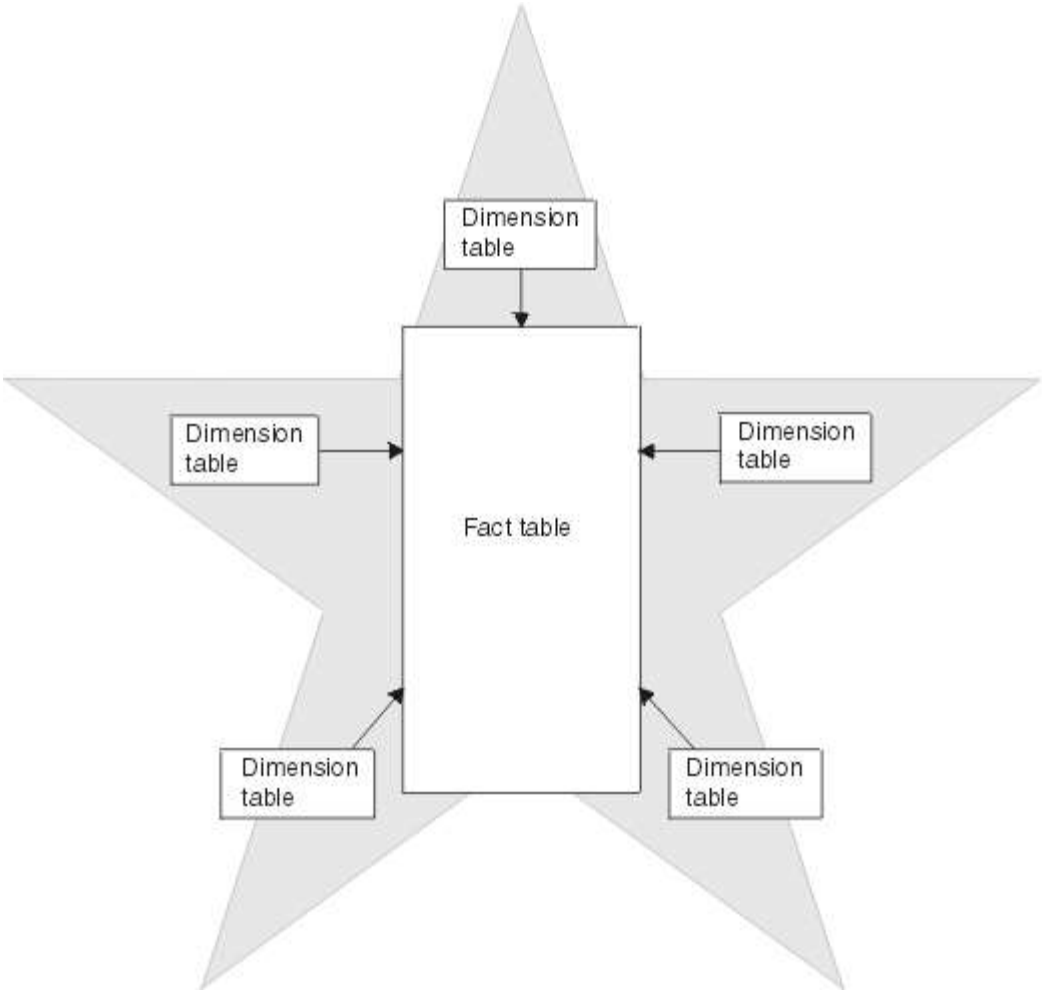
PRACTICE



CONCEPTUAL, LOGICAL, & PHYSICAL DATA MODELS

Star Schema Database Architecture

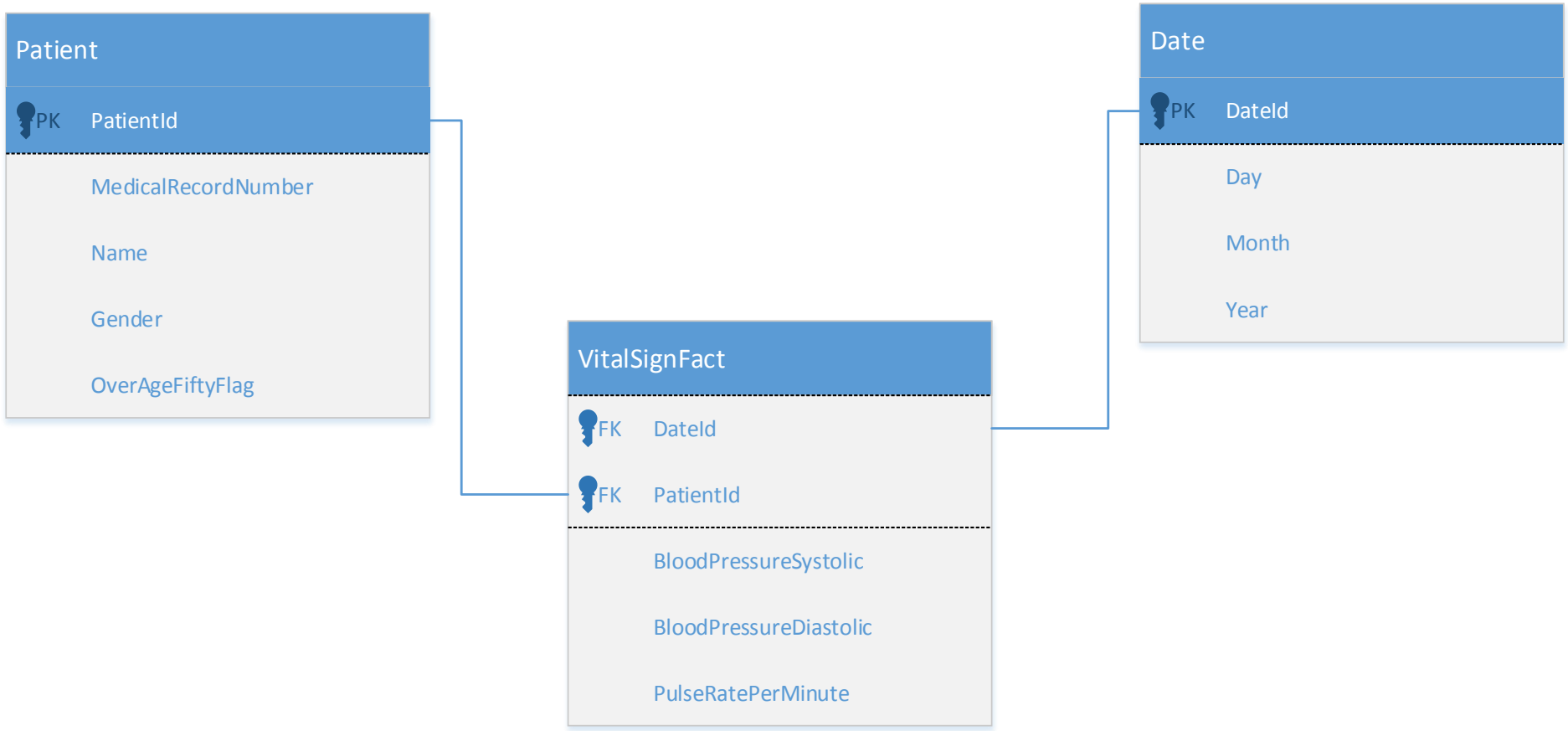
- **Simplest data mart schema**
- **One or more fact tables**
  - Metric data and references
- **Reference any number of dimensions**
  - Descriptive data
  - Fewer records, many attributes
- **Preserve inner join**
  - Easier for ad-hoc reporting
- **Add new descriptive data at any time**
  - Easily add “slices”/“snapshotting” to an existing warehouse



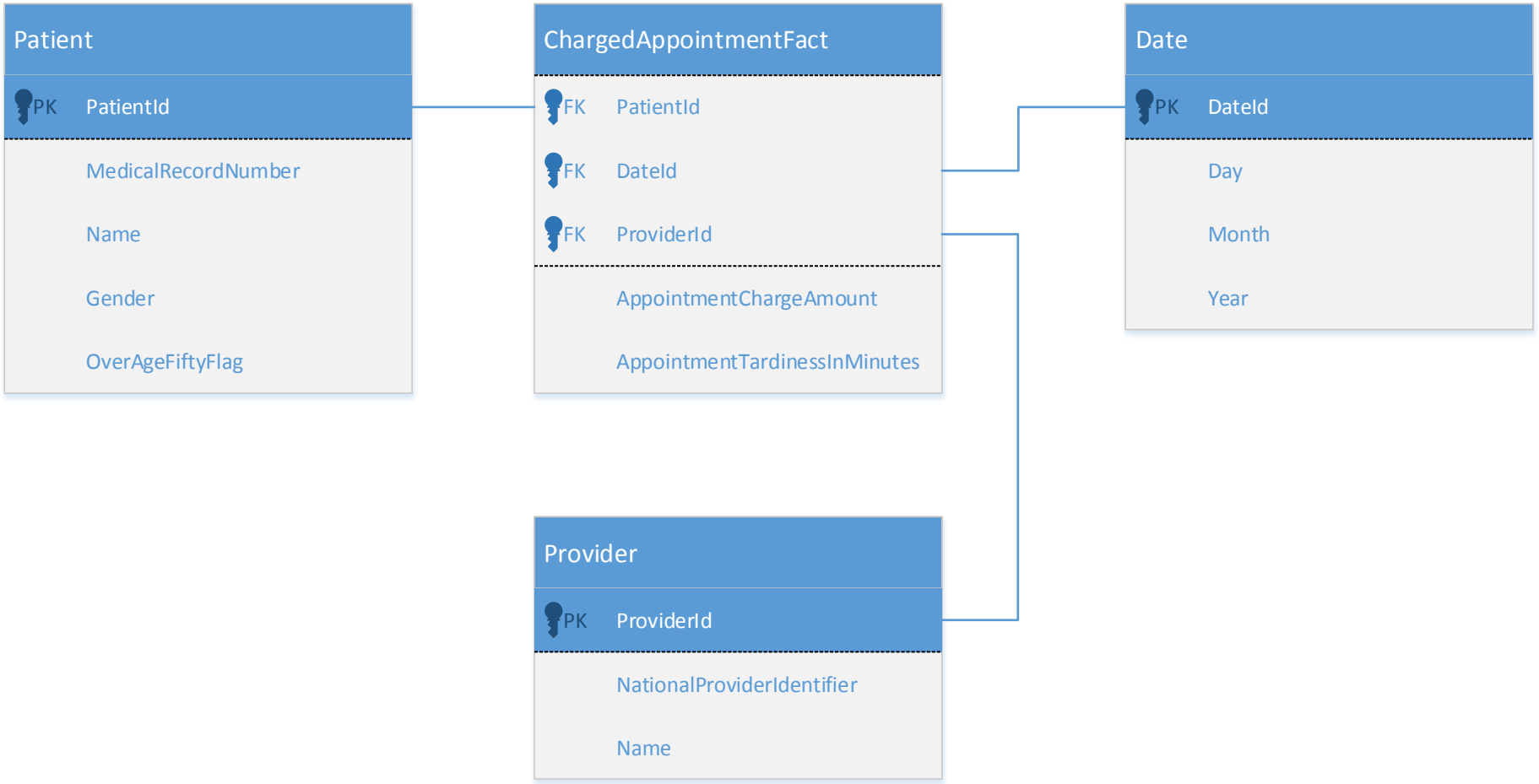
Conceptual Data Model

- **Define the necessary data constructs:**
  - Descriptive/“Dimensional” information:
    - **Patient**
    - **Provider**
    - **Date**
  - Factual Information by Grain:
    - At the **Patient** and **Date** Granularity:
      - Vital Sign Metrics
    - At the **Patient**, **Provider**, and **Date** Granularity:
      - Appointment Tardiness
      - Charge

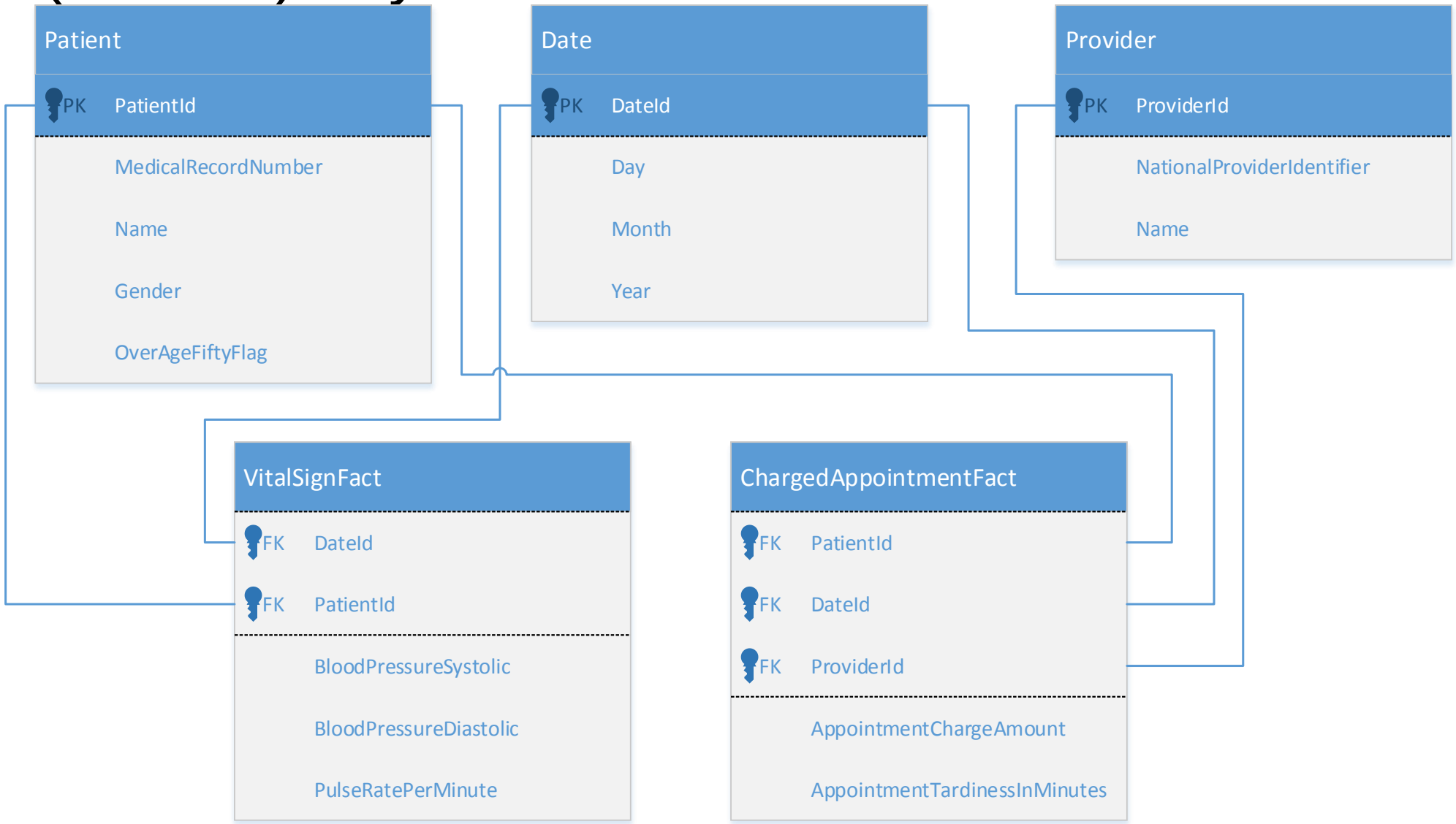
Vital Sign Data Model (Logical, Star Architecture)



Charged Appointment Data Model (Logical, Star Architecture)



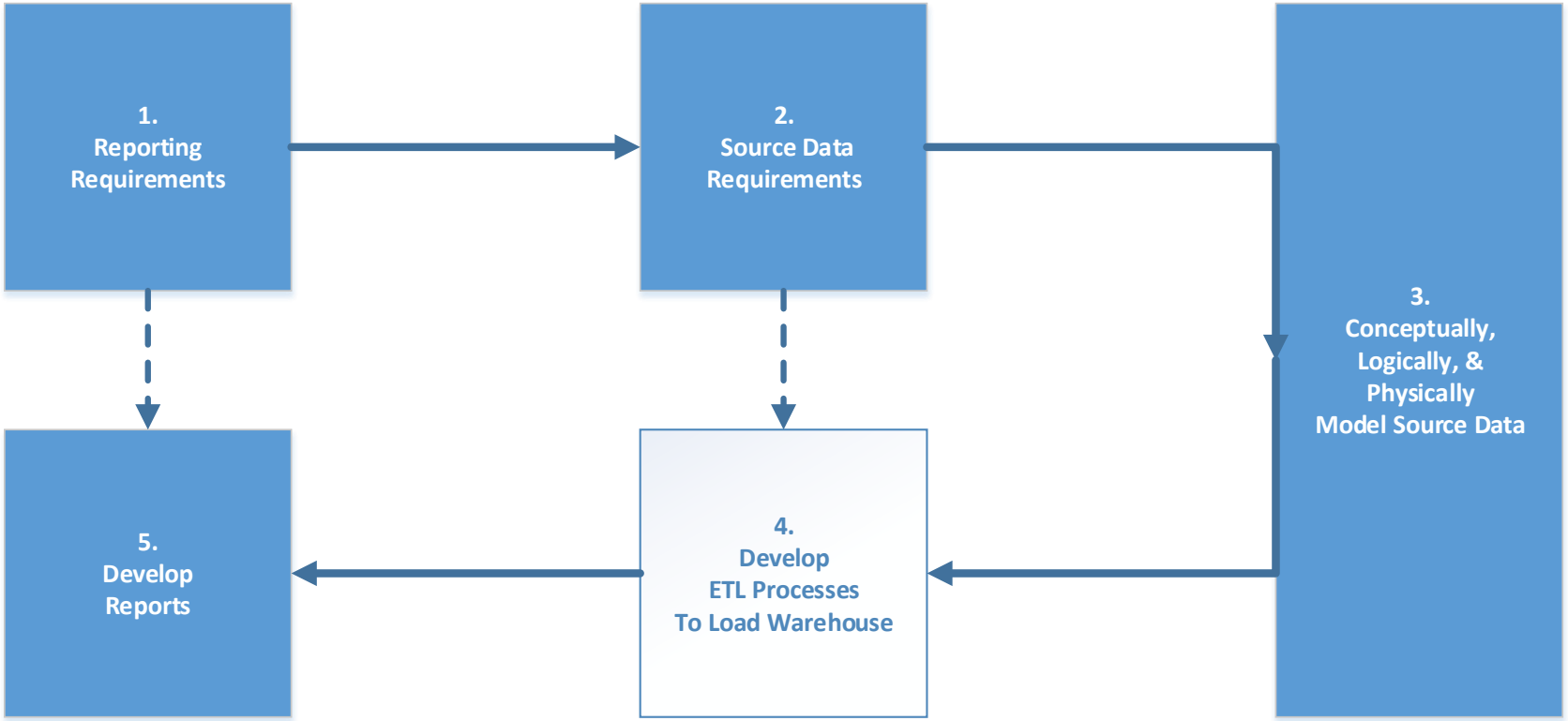
Logical / (Pseudo) Physical Data Model



Poll Question 3

Data Warehousing

PRACTICE



ETL PROCESSING

Extract, Transform, Load

- **Extract Stage**
  - Select necessary data from the source system
    - Potential Methods:
      - Mirror source system “a copy of environment” to use as a source system
      - Script export of factual data, and all necessary descriptive information from source system - Denormalized, “flat file” export
        - » Avoid aggregate functions
    - Any validation logic is applied here
    - Exported data is loaded into the “stage”

Extract, Transform, Load

- **Transform Stage**
  - Extracted data has been loaded into a staging area
  - Common transformations applied to source data within the stage
    - Aggregate/summarize/collapse/rollup data
    - Derive new data from source data
    - Selectively determine what data to load
    - Join data from multiple sources
    - Normalize free form values
    - Transpose/Pivot data
    - Apply pre-defined mappings to source data

Extract, Transform, Load

- **Load Stage**
  - Select transformed data from the stage
  - Dependent upon the warehouse, the load processes may include
    - Updating reference/descriptive/dimensional data
    - Inserting non-overlapping data
    - Upserting/Merging overlapping data
    - Purge old/obsolete data from the warehouse
    - Clean up staging area

ETL for the Example

- **Extract:**
  - The Vital Extract:
    - Select name, gender, MRN, blood pressure, pulse rate, and date
    - From Person/Patient, VitalSignReading, and Appointment
  - The Charge/Appointment Extract:
    - Select provider information, patient information, appointment scheduled and actual start times, dollar amount, and date
    - From Person/Patient, Person/Provider, Appointment, and ChargeDictionary
  - Load extracted data into a staging area designed to hold the results of these queries
  - Note: this is a simple, denormalized, “flat-file” extract

ETL for the Example

```
-- The Vitals Extract
SELECT
     p.Name, p.Gender, p.DateOfBirth, pa.MedicalRecordNumber,
     v.BoodPressureSystolic, v.BloodPressureDiastolic, v.PulseRatePerMinute,
     a.Date
FROM Person p
     INNER JOIN Patient pa ON pa.PersonId = p.PatientId
     INNER JOIN VitalSignReading v on v.PatientId = pa.PatientId
     INNER JOIN Appointment a on a.VitalSignReadingId = v.VitalSignReadingId
WHERE a.Date > @LastExportDateTime

-- The Charge/Appointment Extract
SELECT
     p1.Name as ProviderName, pr.NationalProviderIdentifier,
     p2.Name as PatientName, p2.Gender, pa.MedicalRecordNumber,
     a.Date, a.ScheduledStartTime, a.ActualStartTime,
     cd.DollarAmount
FROM Appointment a
     INNER JOIN Provider pr ON a.ProviderId = pr.ProviderId
     INNER JOIN Person p1 ON pr.ProviderId = p1.PersonId
     INNER JOIN Patient pa ON a.PatientId = pa.PatientId
     INNER JOIN Person p2 ON pa.PatientId = p2.PersonId
     INNER JOIN ChargeDictionary cd ON cd.ChargeDictionaryId = a.ChargeDictionaryId
WHERE a.Date > @LastExportDateTime
```

Transform Extracted Example Data

- **From Vitals Export**
  - Derive OverAgeFiftyFlag from the DateOfBirth and the Date from the Appointment
  - Translate Date to Day, Month, and Year numeric values

- **From Charge/Appointment Export**
  - Derive AppointmentTardiness from ScheduledStartTime and ActualStartTime
  - Translate Date to Day, Month, and Year numeric values

Load Extracted Dimension / Reference Data

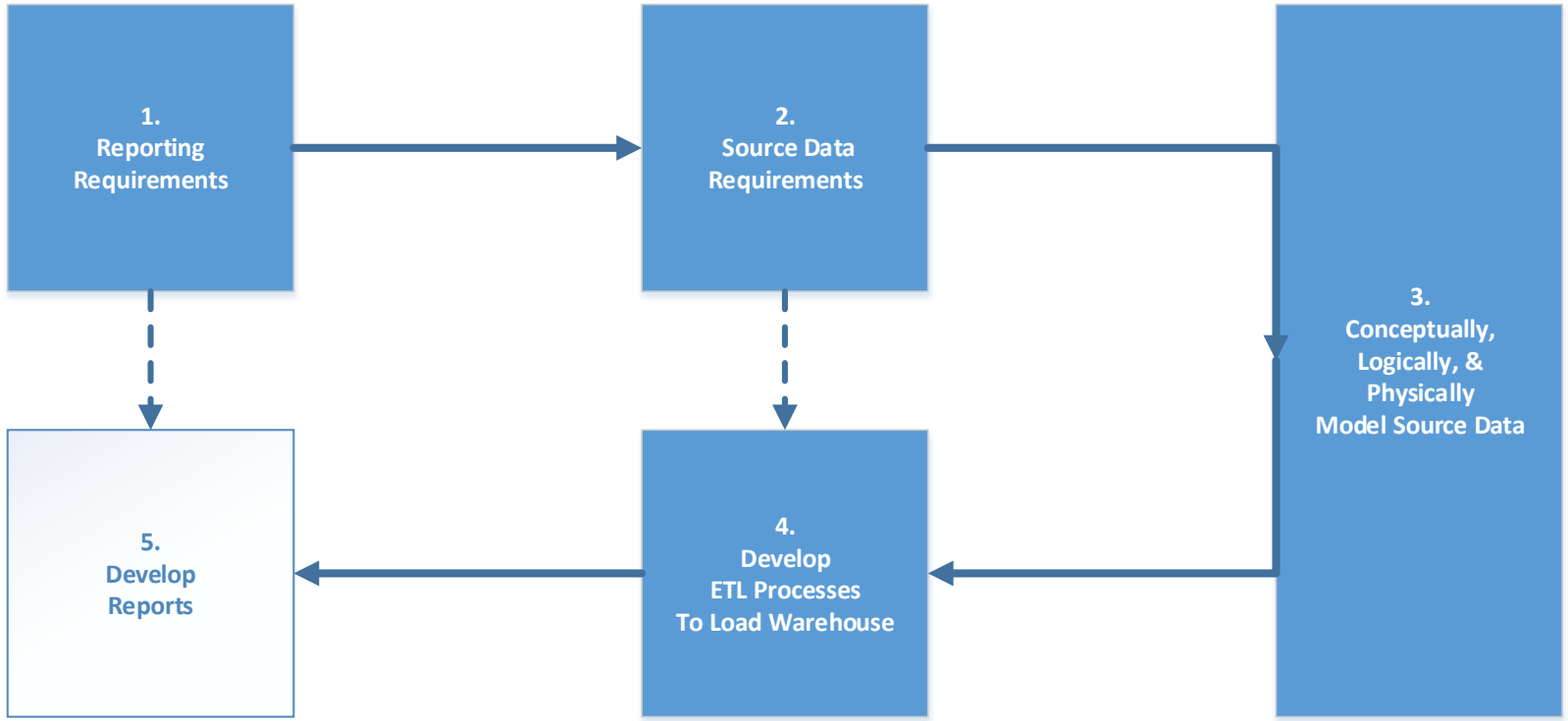
- **For Each Record From Vitals Extract:**
  - Insert any new Day/Month/Year combinations to the Date table from staging
    - Update staging record with DateId
  - Update/Insert to Patient table from transformed staging data
    - Update staging record with PatientId
  - Update/Insert the transformed metrics from staging into VitalSignFact
    - Use the DateId and PatientId found above

Load Extracted Dimension / Reference Data

- **For Each Record From Charge/Appointment Extract:**
  - Insert any new Day/Month/Year combinations to the Date table from staging
    - Update staging record with DateId
  - Update/Insert to Provider table from transformed staging data
    - Update staging record with ProviderId
  - Update/Insert to Patient table from transformed staging data
    - Update staging record with PatientId
  - Update/Insert the transformed metrics from staging into ChargedAppointment
    - Use the DateId, ProviderId, and PatientId found above

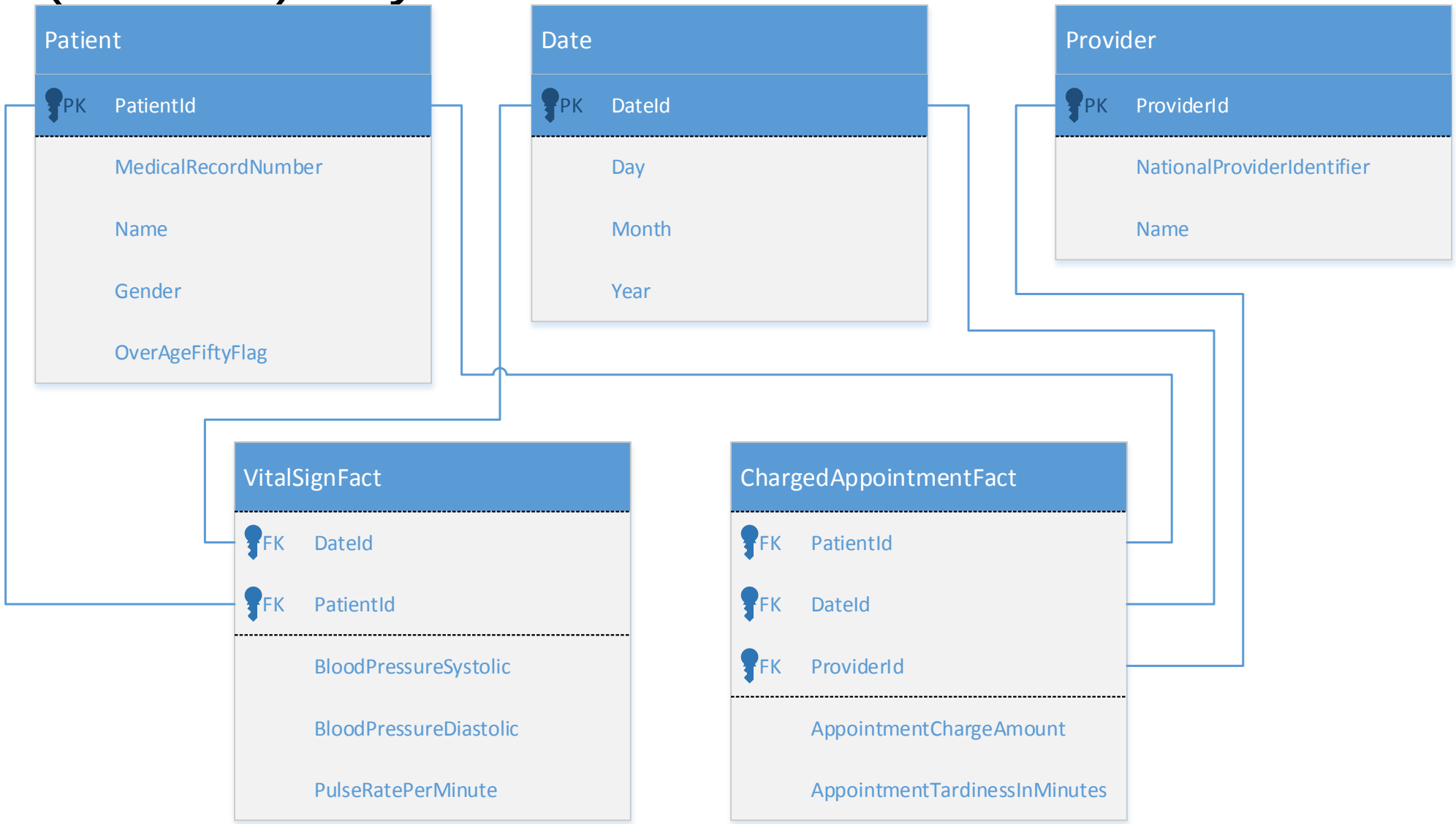
Data Warehousing

PRACTICE



REPORTING

Logical / (Pseudo) Physical Data Model



Report On Warehouse

- **Original Reporting Requirement:**
  - Which patients have seen a rise in both their average blood pressure, and average pulse rate, since last year?
  - Or any interval?

- **Report Design:**
  - Base Query
    - Select from VitalSignFact
    - Use Join to Date to collapse or “group by” the Year
    - Aggregate/Average Blood Pressure and Pulse metrics
  - Join Base query to itself on b1.patient=b2.patient and b1.year=b2.year-1
    - Filter where b1 vital signs are greater than b2 vital signs

Report On Warehouse

- **Original Reporting Requirement:**
  - Which providers are habitually late to appointments?
  - Where habitually means over 15 minutes late on average

- **Report Design:**
  - Using ChargedAppointmentFact and Provider
  - Select Provider Name
  - Group By ProviderId
  - Where Average Tardiness > 15

- **Only care about tardiness this month or year?**
  - Join ChargedAppointmentFact to Date, filter on Month/Year

Report On Warehouse

- **Original Reporting Requirement:**
  - Enable top performer awards – determine total revenue, per provider, per year.
  - Make it work on a monthly scale, too…

- **Report Design:**
  - Using ChargedAppointmentFact and Provider
  - Select Provider Name and Row_Number()
  - Group By ProviderId
  - Sort by Sum of AppointmentChargeAmount descending
  - Join ChargedAppointmentFact to Date, filter on Month/Year

Report On Warehouse

- **Original Reporting Requirement:**
  - Determine advertising campaign target audience:
    - Which gender provided more revenue last year?
    - Were these patients generally under or over 50 years of age?

- **Report Design:**
  - Using ChargedAppointmentFact and Patient
  - Select Patient Name and Row_Number()
  - Group By Gender and/or OverAgeFiftyFlag
  - Sort by Sum of AppointmentChargeAmount descending
  - Join ChargedAppointmentFact to Date, filter on Month/Year

Data Warehousing

SUMMARY

Data Warehouse Development Complete

- **Using Stakeholder requirements, we've successfully used EHR source database to:**
  - Identify necessary data
  - Conceptually, and Logically model data
  - Design (physical data model) and develop a data warehouse
  - Develop ETL process to load warehouse from the EHR source database
  - Define flexible reports to fulfill stakeholder reporting requirements

Was This Exercise Necessary?

- **Could reporting requirements have been fulfilled against the source EHR system?**
  - Yes, but aggregation would cause contention and hinder EHR performance

- **So why not just report off a copy of the source system?**
  - That alleviates the EHR performance concerns
  - Queries are generally unnecessarily complicated
    - more difficult for end user ad-hoc reporting
  - However, the source system does not efficiently enable the aggregation/summarization of vital sign metrics, nor dollar/revenue
    - Reporting queries would become increasingly slow as tables grow

Does this Contrived Data Warehouse provide Benefit?

Business Reasons:

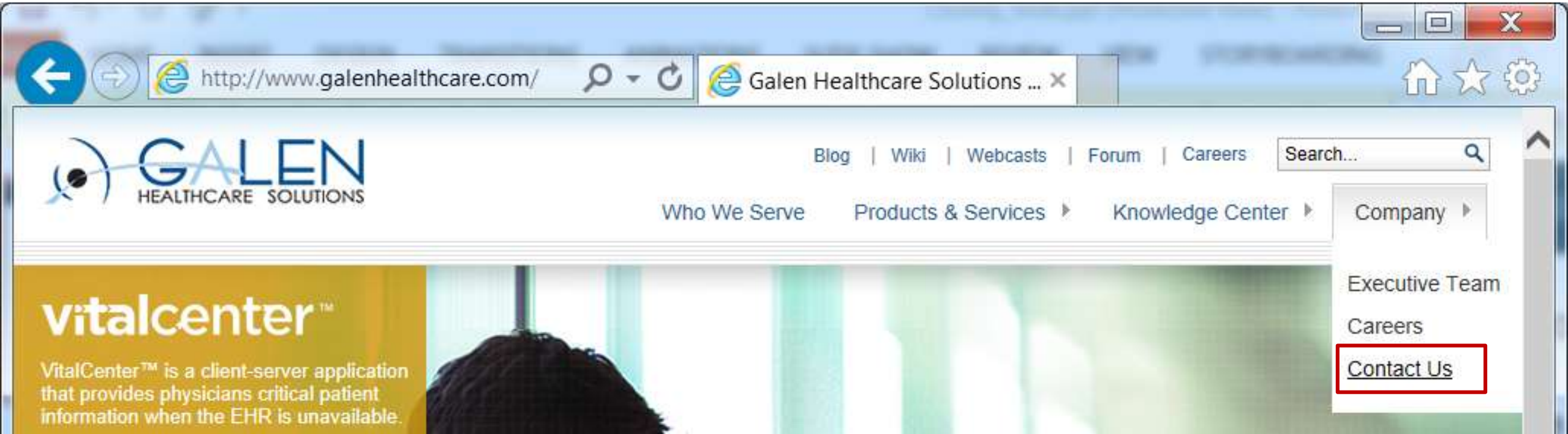
- **High-level (aggregate) reporting**
- **Ad-hoc (custom, end user) reporting**

Technical Reasons:

- **Restructure data to make sense for business users (enable ad-hoc reporting)**
- **Restructure data for performance, without impacting operational systems**
- **Alleviated the contention cause by running analytic queries against transaction processing systems**

Data Warehousing

- **Thank you for joining us today**
- **You may contact us through our website at:**
  - http://www.galenhealthcare.com



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Questions?

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