Constraints

1) The difference between the set of pID from the Staff relationship and the pID from the Patient relationship is the empty set. The staff's pID is a subset of the pID in the Patient relation. Since the staff includes doctors and nurses that require medical care, the staff are also assigned with a pID.
2) The adID or atID or both adID and atID of the Vaccination relation must also be in the sID of the Staff relation. adIDs are assigned to nurses whereas atID are assigned to doctors hence, it would make sense since they are also "staffs" and they could also be viewed as the staff's id.
3) Every specialty from the Staff relation must also be in the set of {'RN', 'RPN', 'MD', 'Pharmacist'}. The medical staff will be required to have different roles such as registered nurse, registered psychiatric nurse, medical doctor as well as pharmacist in order to perform their designated tasks.
4) The pID of a patient in the Vaccination relation must also be in the pID of a patient in the Patient relation. All the individuals that are vaccinated can also be viewed as patients hence, they are assigned a patient id that corresponds to the Patient relation.
5) The difference between the set of bID from the Vial relationship and the bID from the Batch relationship is the empty set. The vial's bID is a subset of the bID in the Batch relation. Since the vials are produced in batches, we would expect each vial to have a bID corresponding to the bid of the batch it was produced by.
6) Every covidStatus from the Vaccination relation must also be in the set of {'positive', 'negative'}. This is to indicate whether the patient has the coronavirus.
7) Every reaction from the Vaccination relation must also be in the set of {true, false}. This is to indicate whether the patient has reacted to the vaccine given.
8) Every mID in the Batch relation must also be in the mID in the Manufacturer relation. Each batch would have an mID corresponding to the manufacturer's mID of the vaccine.
9) The difference between the set of bID from the Tracking relationship and the bID from the Batch relationship is the empty set. Since the vaccine batches are produced and shipped, we would expect each batch that is tracked to have corresponding ids to the bID of the vaccine batches produced.
10) The difference between the set of vID from the Vaccination relationship and the vID from the Vial relationship is the empty set. Each patient will be vaccinated with a vial hence, the vID of the vial used for the vaccination has to correspond with the vID from Vial that was removed from the cold storage to be used.

Queries

1)

Query 1:

$\Pi_{pID}(\sigma_{dose\_count = 0 \wedge date >= 2020-12-01}(Vaccination \bowtie Vial))$

pID of all patients who have received all required doses since the beginning of December 2020

Query 2:

$ManufacturersVaccine(mID) := \Pi_{mID} Manufacturer$

the manufacturers of the vaccine

$Location(locationName) := \Pi_{locationName} Tracking$

the location that the batch of vaccine is shipped to

$ShouldHaveBeen(locationName, mID) := \Pi_{locationName, mID} Tracking \times ManufacturersVaccination$

imagine every location have used vaccine from every manufacturer in the vaccinations

$WereNotAlways(locationName, mID) := ShouldHaveBeen - Location$

these are the instances of a location missing a manufacturer's vaccine

$Answer(locationName) := (\Pi_{locationName} Location) - (\Pi_{locationName} WereNotAlways)$

subtract the locations that does not use vaccination from every manufacturer

2)

Query 1:

$WaitingForDoseLongerThanRecommended(vID) := \Pi_{vID}(\sigma_{dose\_count>0 \wedge today-date>intervalMax}(Vial \times Vaccination \times Manufacturer))$

vials that contain a subsequent dose that is more than the number of days recommended by the manufacturer

$\Pi_{pID} WaitingForDoseLongerThanRecommended \bowtie Vaccination$

the patients that are waiting for the dose

Query 2:

$$VialThawedLongerThanRecommended(vID) := \Pi_{vID}(\sigma_{date-thawTime>thawMax}(Vial \times Vaccination \times Manufacturer))$$

vials that are thawed longer than recommended by the manufacturer

$$\Pi_{adID} VialThawedLongerThanRecommended \bowtie Vaccination$$

staffs that administered the vaccine from the vial that is thawed longer than recommended

Query 3:

$$VialThawedLongerThanRecommended(vID) := \Pi_{vID}(\sigma_{date-thawTime>thawMax}(Vial \times Vaccination \times Manufacturer))$$

vials that are thawed longer than recommended by the manufacturer

$$AtLeastFiveTimes(vID) := \Pi_{V1.vID}$$

$$\sigma_{V1.vID=V2.vID=V3.vID=V4.vID=V5.vID \wedge (V1.pID<V2.pID<V3.pID<V4.pID<V5.pID)}$$

$$[(\rho_{V1} Vaccination) \times (\rho_{V2} Vaccination) \times (\rho_{V3} Vaccination) \times (\rho_{V4} Vaccination) \times (\rho_{V5} Vaccination)]$$

vials with at least 5 doses used on patients

$$AtMostFourTimes(vID) := (\Pi_{vID} Vaccination) - AtLeastFiveTimes$$

vials with four or fewer doses used

$$Answer(vID) := \Pi_{vID} AtMostFourTimes \bowtie VialThawedLongerThanRecommended$$

3)

Query:

$pIDVaccinatedby42(pID) := \Pi_{pID}\sigma_{adID=42 \vee atID=42}Vaccination$

patients that are administered or attended by staff sID 42

$sIDVaccinatedby42(sID) := \Pi_{sID}Staff \bowtie pIDVaccinatedby42$

staff ID of the patients above

$adIDatIDVaccinated42(adID,\ atID) := \Pi_{adID,\ atID}\sigma_{pID=42}Vaccination$

staffs that administered or attended sID 42's vaccination

$\Pi_{sID,\ adID,\ atID}sIDVaccinatedby42 \times adIDatIDVaccinated42$

all staffs that are exposed to covid-positive staff sID 42

4)

Query:

$(\Pi_{adID}Vaccination) \bowtie (\Pi_{atID}Vaccination)$

staff that both administer vaccines and attend patients

5)

Query 1:

$Batches(bID,\ mID,\ productionDate) := \Pi_{bID,\ mID,\ productionDate} Batches$

the bID, mID and productionDate from Batches

$OldBatches(bID,\ mID,\ productionDate) := \Pi_{B1.bID,\ B1.mID,\ B1.productionDate} \sigma_{B1.productionDate < B2.productionDate} [(\rho_{B1} Batch) \times (\rho_{B2} Batch)]$

the batches of vaccine that are not the most recently produced

$NewestBatch(bID,\ mID,\ productionDate) := Batches - OldBatches$

the newest batch of vaccine produced

$ModernaID(mID) := \Pi_{mID} \sigma_{name='Moderna'} Manufacturer$

the manufacturer ID of the vaccine producer, Moderna

$NewestBatchFromModerna(vID) := \Pi_{vID} NewestBatch \bowtie ModernaID \bowtie Vial$

the vaccine vials that are from the newest batch produced by Moderna.

$\Pi_{adID} \sigma_{reaction='true'} Vaccination \bowtie NewestBatchFromModerna$

the staff that administered the most recent Moderna vaccine that had a bad reaction

Query 2:

$pID\&vIDFromVaccination(pID,\ date,\ vID,\ covidStatus) := \Pi_{pID,\ date,\ vID,\ covidStatus} Vaccination$

patient and vial IDs plus date and covidStatus from Vaccination

$VialbID(bID,\ pID,\ date,\ vID,\ covidStatus) := \Pi_{bID,\ pID,\ vID,\ date,\ covidStatus} Vial \bowtie pID\&vIDFromVaccination$

enable us to track the bID in order to determine the location from Tracking

$TrackingLocationName(locationName,\ bID,\ pID,\ date,\ vID,\ covidStatus) := \Pi_{locationName,\ bID,\ pID,\ date,\ vID,\ covidStatus} Tracking \bowtie VialbID$

projection consisting of batch IDs, patient IDs, vial IDs, date and patient covidStatus plus the locationName to track ‘Ontario’

$\Pi_{P1.pID} \sigma_{P1.pID = P2.pID \wedge P1.locationName = 'Ontario' \wedge P1.covidStatus='negative' \wedge P2.covidStatus='positive' \wedge P2.date > P1.date} [(\rho_{P1} TrackingLocationName) \times (\rho_{P2} TrackingLocationName)]$

Relational Algebra Expression for Constraints

1)

$$\Pi_{V1.vID}(\sigma_{V1.vID = V2.vID \wedge V1.bID != V2.bID})[(\rho_{V1} Vial) \times (\rho_{V2} Vial)] = \emptyset$$

2)

$$pID\&vIDFromVaccination(pID, vID) := \Pi_{pID, vID} Vaccination$$

patient and vial IDs from Vaccination

$$VialbID(bID, pID, vID) := \Pi_{bID, pID, vID} Vial \bowtie pID\&vIDFromVaccination$$

relation consisting of batch, patient and vial IDs

$$BatchmID(mID, bID, pID, vID) := \Pi_{mID, bID, pID, vID} Batch \bowtie VialbID$$

relation consisting of manufacturer, batch, patient and vial IDs.

$$\Pi_{B1.pID}\sigma_{B1.pID = B2.pID \wedge B1.mID != B2.mID}[(\rho_{B1} BatchmID) \times (\rho_{B2} BatchmID)] = \emptyset$$

there are no patients that receives vaccines from two different manufacturers

3)

$$\Pi_{P1.pID}(\sigma_{P1.pID = P2.pID = P3.pID \wedge P1.date < P2.date < P3.date}[(\rho_{P1} Vaccination) \times (\rho_{P2} Vaccination) \times (\rho_{P3} Vaccination)] = \emptyset$$

4)

$$(\Pi_{adID}(Vaccination) \wedge \Pi_{atID}(Vaccination)) \subseteq \Pi_{pID}(Vaccination)$$

5)

$$pID\&vIDFromVaccination(pID, vID) := \Pi_{pID, vID} Vaccination$$

patient and vial IDs from Vaccination

$$VialbID(bID, pID, vID) := \Pi_{bID, pID, vID} Vial \bowtie pID\&vIDFromVaccination$$

included the batchID in order to determine the locationDate of the vaccine's arrival

$$TrackingLocationDate(locationDate, bID, pID, vID) := \Pi_{locationDate, bID, pID, vID} Tracking \bowtie VialbID$$

used the batchID to determine the location date of the vaccine's arrival

$$\Pi_{pID}\sigma_{locationDate > date}(TrackingLocationDate) = \emptyset$$

there are no patients that receives vaccines before it arrives