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A Dedicated Perfusion Electronic Medical Record with Discrete Epic Integration

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Abstract: Enterprise electronic medical records (EMR) have largely become a standard since their use was mandated by The American Recovery and Reinvestment Act of 2009. However, perfusion departments have adopted true perfusion EMRs at various rates. In our efforts to integrate with the institutions EMR while enjoying the benefits of an EMR designed specifically for perfusion practice, we developed a discrete data integration solution between Epic and the Spectrum Medical VIPER Perfusion EMR. This report describes our perfusion EMR selection criteria, design challenges, and documentation process. **Keywords:** VIPER, electronic medical record, electronic perfusion record, perfusion record integration, Epic. *J Extra Corpor Technol. 2017;49:291–298*

Enterprise electronic medical records (EMR) have largely become a standard since their use was mandated by The American Recovery and Reinvestment Act of 2009 (1). However, perfusion departments have adopted true perfusion EMRs at various rates. Many departments scan manually recorded paper records and add that media to the enterprise EMR. Others provide integrated data capture directly to the institutional EMR (2). Some use a dedicated perfusion EMR that generates a portable document format (PDF) (Adobe Acrobat, San Jose, CA) record and electronically transfer that document to the institutions EMR. Unfortunately, each of these approaches has caveats including the inability to data mine information in scanned documents. In many cases, it is not possible to capture all of the electronically obtainable information without manual documentation. In an invited commentary to the Steffens and Gunser paper, Riley and Justison (3) point out a widespread solution to export automatically collected perfusion data from a third party device and transfer that data to an institutional EMR had not yet been developed. In our efforts to become integrated with the institutions EMR while enjoying the benefits of an EMR designed specifically for perfusion practice, we developed a solution for use with the Spectrum Medical VIPER Perfusion EMR (Spectrum Medical, Fort Mill, NC). In cooperation with Spectrum Medical and our in house information technology team, an interface was established between the VIPER EMR and the Epic Systems Corporation EMR (EpicCare EMR, Verona, WI).

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SYSTEM SELECTION AND DEVELOPMENT

In our search for a perfusion EMR, we took into account several significant capabilities we felt were necessary to completely harness the advantages of electronic data capture. Those abilities included vendor neutrality, extent of device integration, case reconstruction, remote surveillance, easily accessible and highly capable data mining capabilities, by the second data capture and preservation, quality metrics monitoring, real time physiological parameter alerts, and enterprise integration. At the time of our investigation, we used the Maquet HL20 (Maquet, Wayne, NJ) heart-lung machine (HLM) equipped with the JOCAP EMR (Maquet). After our experience with JOCAP, we explored the options available from Epic and Spectrum Medical. Bearing in mind a possible transition to the LivaNova S5 (LivaNova, Lonon, UK) HLM platform,

we considered the Connect (LivaNova) as well. Our investigation revealed that it is possible to modify components of the Epic EMR for use as a perfusion or combined anesthesia/perfusion record as Steffens et al. (2) have reported. Although that solution does provide some advantages pointed out by Steffens such as the ability for anesthesia and perfusion to see all recorded data in the same location in real time (2), not all of the previously stated capabilities are available on that platform including second by second data collection for case reconstruction and surveillance, real time alerts, and case by case quality metrics. The Connect system did not provide the capability of discrete enterprise EMR integration, physiological parameter alerts, remote surveillance, or HLM vendor neutrality. Ultimately, we chose the only system that provided all of the requirements to our satisfaction, the Spectrum Medical VIPER.

On installation of the VIPER system, enterprise integration began as is does at many institutions. A PDF was generated with the appropriate parameters to be included in a perfusion record per American Society of ExtraCorporeal Technology's (AmSECT) Standards and Guidelines for Perfusion Practice (4). At the end of each case, the document was printed, manually signed, placed in the patient's paper chart, and eventually scanned into the enterprise electronic record. Soon after implementation of this strategy, in cooperation with Spectrum Medical and our health information management (HIM) team, the system was configured to automatically transmit the PDF to HIM via e-mail at the end of each cardiopulmonary bypass (CPB) case. HIM entered the document into the ChartMaxx (Quest Diagnostics, Madison, NJ) media management system. The primary perfusionist on the case would electronically sign the record in the ChartMaxx interface. The document was then uploaded to Epic. Although this system eliminated the need for physical paper documents, it still required significant human interaction and too many steps were necessary for the process to be efficient. In addition, data mining from the document via Epic was still unavailable and the location of the document was difficult to find, buried in the media tab. The ultimate goal for the perfusion record was discrete data entry into the Epic record in a consistently accessible location familiar to providers. The data should also be readily available for inclusion in dot phrases incorporated in operative reports and progress notes, dashboards and registries. A little over a year after implementation of the VIPER system, the project to send discrete data to an Epic documentation flowsheet began. The project spanned 11 months and encountered unexpected but not insurmountable technical and practical clinical obstacles. The technical obstacles resolved during testing including data selection, modification, deletion, and transfer are out of the scope of this report but the practical issues are described in the later paragraphs. Our institution uses the VIPER system for both CPB and ECMO cases and each of these applications provide unique challenges to the documentation integration.

CARDIOPULMONARY BYPASS CASE DOCUMENTATION

During CPB the VIPER system is the clinician's primary interface for the perfusion record (Figure 1). All information electronically generated is captured by the VIPER. Data from the physiological and NIRS monitors, HLM, heater-cooler, CDI 500 (Terumo Cardiovascular, Ann Arbor, MI), Medtronic Heparin Management System (Medtronic, Minneapolis, MN), ABL90 FLEX blood analyzer (Radiometer, Brea, CA) and M4 (Spectrum Medical) is captured as it is produced as often as every second or at the limit of the device producing the data (Table 1).

A barcode scanner is used when a barcode is available to reduce manual data entry errors. This includes scanning disposable lot and expiration numbers, blood product numbers and patient armbands. Scanning a patent's armband barcode in combination with the admission, discharge and transfer (ADT) interface implemented during this integration, ensures patient demographic information accuracy. Before each case the patient's information is scanned, matched with the ADT feed to the VISION server and pulled into the VIPER record. The information obtained includes the patient's first, middle and last name, medical record number, hospital account number, and date of birth. Assuming the correct armband is scanned, this method of data entry ensures the accuracy of the patient's demographic information associated with the pump record facilitating downstream integration with lab values and Epic integration.

All data along with manually entered information such as clinical personnel, prime constituents, equipment serial numbers, patient history, diagnosis, allergies, procedure, medication and fluid administration, anesthetic gas rate, events, and comments is stored in the VISION database at the close of the case. The selected data is then transmitted to an Epic documentation flowsheet labeled "CPB."

Documentation in Epic is generated for charted activity before going on bypass such as lab times, heparin administration, and other events deemed appropriate for documentation by the clinician. Once on CPB and at the time of CPB initiation, predicted patient blood volume, predicted on CPB hematocrit, target cardiac index (CI), clinical personnel, prime constituents (Figure 2), equipment, and disposables (Figure 3) are documented. The values shown in Table 1 and denoted with an asterisk are documented with each event during CPB such as clinician change, medication administration, free text comments,

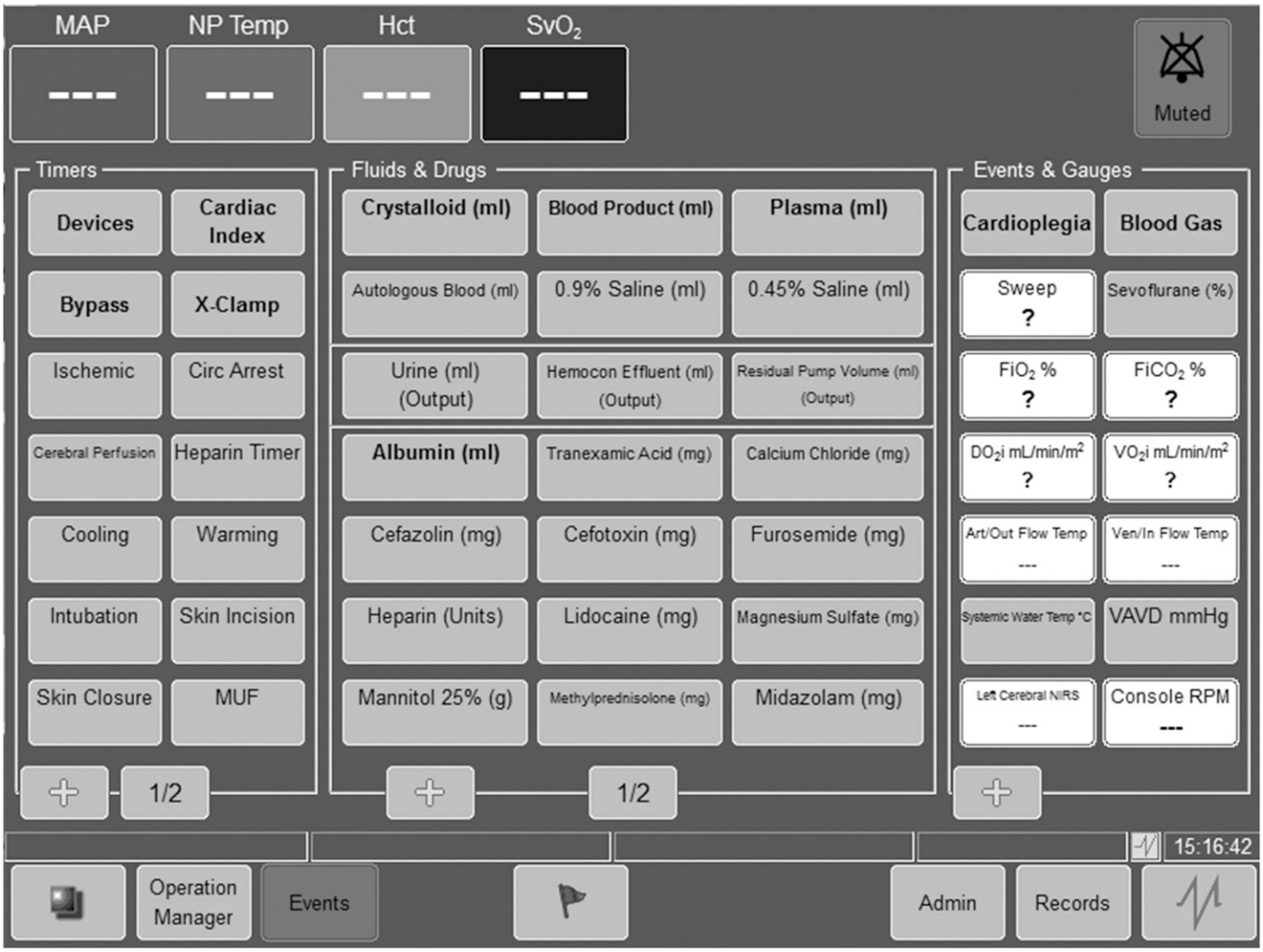


Figure 1. VIPER interface.

cooling, warming, cross-clamp on/off, etc. The same values are also documented every five minutes in the absence of an event.

Once off CPB, documentation is generated for modified ultrafiltration parameters and events after CPB including lab times, protamine administration, skin closure, etc. The final column documented includes CPB, cross-clamp, circulatory arrest, ischemic and regional perfusion times, and fluid balance (Figure 4).

After the case, the clinician reviews the record in Epic and incorporates a dot phrase attestation in a procedure note. The attestation reads; "*The Cardiopulmonary Bypass (CPB) flowsheet record for (date of the procedure) accurately reflects the actions taken, patient's hemodynamic status, heart lung machine settings, and medications, blood products and fluids administered in my capacity as a Cardiovascular Perfusionist during the time I provided CPB under the order of the attending physician. I do hereby attest that this information is true, accurate and complete to the best of my knowledge.*"

As recommended by the AmSECT Standards and Guidelines for Perfusion Practice, a checklist is completed for each case and included as part of the patient's permanent record (4). The VIPER EMR has a customizable checklist feature that we have modified to fit our institutional practice. At the end of the case, the checklist is transmitted to HIM via e-mail, uploaded to Epic, and stored in the media tab.

ECMO CASE DOCUMENTATION

All information electronically generated during an ECMO run is captured by the VIPER. Data from the

Table 1. Electronically generated and collected parameters.

Arterial and venous Flow*†	Left, Right Cerebral and Somatic NIRS	Console Pump Flow*†	Base Excess
Micro bubble activity	Level sensor activity	CDI temperature	CPG,* MUF,* arterial line*† and venous reservoir pressures*
CPG,* MUF,* arterial,*† venous* and water bath*† temperatures	CVP,*† PA and LA pressure	Core/patient temperature*†	CDI HCO_3
CDI and M4 hemoglobin	CDI and M4 hematocrit	CDI potassium	LA pressure
CDI $PaCO_2$	Console pump RPM*†	CDI and M4 SaO_2	CDI and M4 SvO_2
CDI pH	Systolic, diastolic and mean systemic blood pressure*†	Nasopharyngeal temperature	Sweep*†
FiO_2*†	$FiCO_2$*†	DO_2	VO_2
Cardiac index*†	Pulse oximeter†	CDI PaO_2	Heart rate*†
CPG flow*	CPG route*	CPG delivery duration*	CPG volume delivered*
ECMO bypass hour†	Pre-membrane pressure high limit†	Arterial line pressure high limit†	Venous line pressure low limit†
Arterial line temp high and low limit†	Arterial flow high and low limit†	Pre and post-membrane delta pressure†	Venous line pressure†

*Values documented in the Epic CPB flowsheet.
†Values documented in the Epic ECMO flowsheet.

physiological and NIRS monitors, CDI 500, CardioHelp (Maquet) or HL20 and M4 is captured every three seconds or at the limit of the device producing the data. This data along with manually entered information such as clinical personnel, allergies, diagnosis, prime constituents, equipment serial numbers, disposable lot numbers, patient demographics and history, medication and fluid administration, water bath temperatures, events and comments is stored in the VISION database. As ECMO often lasts days and sometimes weeks, the data is transmitted in near real time as the ECMO run progresses and data transmission concludes on decannulation and the closure of the VIPER record.

As a part of this project, documentation nomenclature was standardized between the CPB and ECMO flowsheets. In similar fashion to the CPB record, documentation is generated for events before going on ECMO such as cannulation times, heparin administration and other events deemed appropriate for documentation by the clinician. Once on ECMO and at the time of ECMO initiation, predicted

	1235
Priming Constituents	
Crystalloid (mL)	0
Washed PRBC (mL/unit number)	120/W0[redacted]
PRBC (mL/unit number)	0
FFP (mL/unit number)	120/W0[redacted]
0.45% Saline (mL)	150
0.9% Saline (mL)	0
Medication 1 value units	Albumin 50 mL
Medication 2 value units	Calcium Chloride 60 mg
Medication 3 value units	Cefuroxime 180 mg
Medication 4 value units	Heparin 2000 Units
Medication 5 value units	Methylprednisolone 105 mg
Medication 6 value units	Sodium Bicarbonate 7 mEq
Medication 7 value units	Tranexamic Acid 361 mg
Medication 8 value units	
Medication 9 value units	
Ultrafiltrate Volume (mL)	115
Total Prime Volume (mL)	341.69

Figure 2. Prime constituent documentation.

Disposables	
Base Pack/Lot Number	Terumo/1718063010UL12
Oxygenator/Lot number	FX05/01049873507817721719...
Tubing Pack/Lot Number	3/16 X 1/4/1718083110UL26
Hemoconcentrator/Lot Number	Sorin DHF02/+M14902049770...
Cardioplegia Set/Lot Number	Sorin CSC14/+M14962731590...
Arterial cannula 1/Lot Number	Med DLP Art 8FR/2016070505
Arterial cannula 2/Lot Number	Med DLP Art 8FR/
Venous cannula 1/Lot Number	Med RA Metal OT 16FR/2016...
Venous cannula 2/Lot Number	
Venous cannula 3/Lot Number	
Vent - Sump 1/Lot Number	Med Malleable 13FR/201606437
Vent - Sump 2/Lot Number	Med Sump 12 FR/2016040529
Cardioplegia Cannula/Lot Number	Medtronic Antegrade 18GA/20...
VAVD System/Lot Number	
Equipment	
Pump/Serial Number	HL-20/94002157
Patient Monitor	Solar 8000
Inline Monitor/Serial Number	CDI 500/5190
Oximeter	Invos
Blood Gas Machine	ABL 90
ACT Machine	HMS Plus
Heater-Cooler/Serial Number	Sorin 3T/16S17096
Autotrasfusion System/Serial Number	Fresenius CATS/2CAT4795

Figure 3. Equipment and disposable documentation.

	Admission (Current) from 11/29/2016 in B6HI					
	12/21/16					
	1657	1725	1747	1759	1805	1849
ECLS						
CPB Time						02:46
Cross Clamp Time						01:49
Donor Organ Ischemic Time						0
Circulatory Arrest Time						00:35
Cerebral Perfusion Time						00:48
Events						
Event	{}Lab Results	{}Lab Results	Skin Closure {}		{}Lab Results	
Comment	{}	{}	{}		{}	
ECLS Vitals						
Systolic Blood Pressure (mmHg)	77	60	78	75	70	
Diastolic Blood Pressure (mmHg)	38	30	37	36	33	
Mean Blood Pressure (mmHg)	53	42	52	51	47	
Central Venous Pressure (mmHg)	9	6	8	9	7	
Heart Rate (BPM)	155	160	168	170	174	
Patient Temperature C(F)	37.1	37.2	37.3	37.4	37.5	
ECLS Pump						
Out/ART Flow (L/min)						
In/VEN Flow (L/min)						
Cardiac Index (mL/kg/min)						
Cardiac Index (L/min/m2)						
Console Flow (L/min)						
Console Speed (RPM)						
Oxygenator Settings						
FiO2 (%)						
FiCO2 (%)						
Sweep (L/min)						
Sevoflurane (%)						
System Pressures						
Out/ART Line (postmembrane) (mmHg)						
Venous Reservior Pressure (mmHg)						
VAVD Set Point (mmHG)						
System Temperatures						
Out/ART Line (postmembrane) C(F)						
In/VEN C(F)						
Systemic Water Bath C(F)						
Hemofilter						
Effluent Volume (mL)						1900
Fluid Balance (mL)						3.77

Figure 4. Final column.

patient blood volume, predicted on ECMO hematocrit, prime constituents, target CI, personnel, equipment, and disposables are documented in an Epic documentation flowsheet labeled MCS/ECLS. While on ECMO, the parameters listed in Table 1 and denoted with an † are recorded with every event such as clinician change, medication administration, free text comments, circuit safety checks, etc. and at a minimum of every 15 minutes on the quarter of the hour (Figure 5). Once off ECMO, documentation is generated for events after ECMO including cap trial times and line flashes until decannulation is documented. Similar to CPB, the ECMO application also includes a customized checklist that is uploaded to Epic and stored in the media tab at the conclusion of the run.

DISCUSSION

During the investigational period of this process, the question arose regarding the management and retention of collected data that is not made a part of the patient's medical record. These data are stored on the password protected VISION server within the institutions network. The data are considered meta data by our legal department and are retainable per institutional protocols.

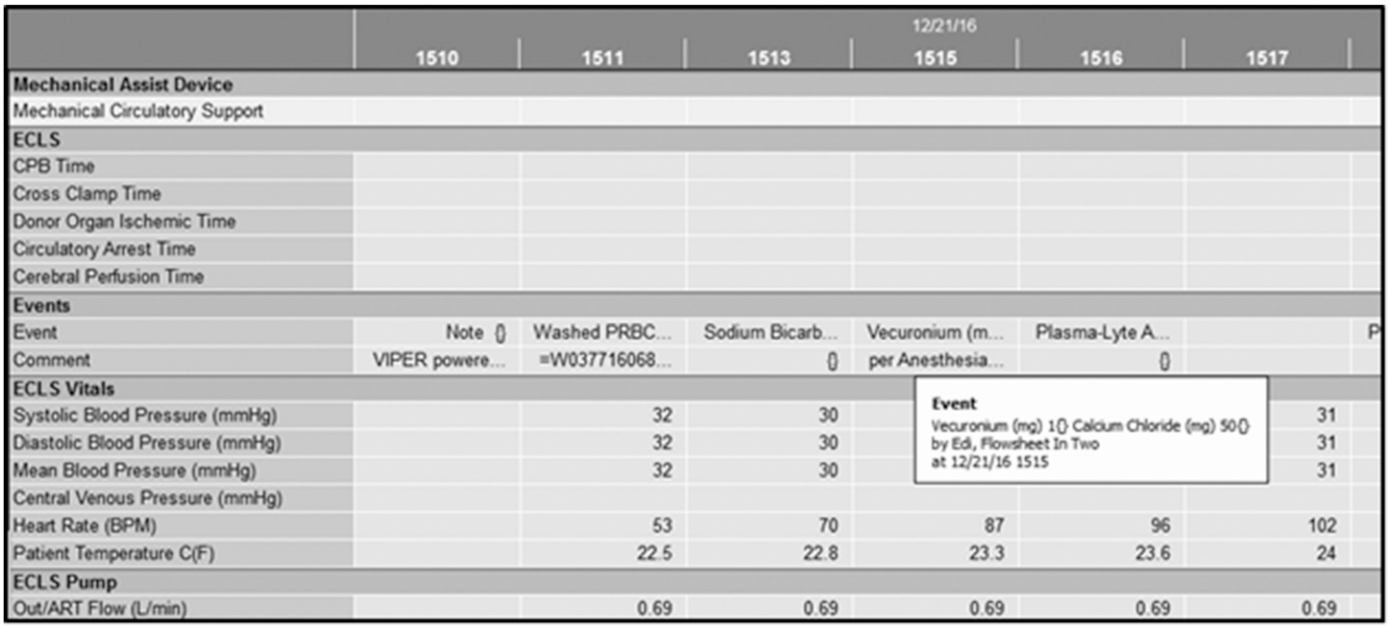
	Admission (Current) from 12/17/2016 in B6HI				
	12/23/16				
	1115	1130	1138	1139	1140
ECLS Bypass Hour	134	134	134	134	134
Events					
Event			Tubing Secure...	Clot Assesme...	Vapor Port{}PR...
Comment			Yes{}Yes{}No I...	In/VEN cannul...	Gas flow prese...
ECLS Vitals					
Systolic Blood Pressure (mmHg)	77	70	68	68	69
Diastolic Blood Pressure (mmHg)	57	49	46	46	47
Mean Blood Pressure (mmHg)	64	58	55	55	56
Central Venous Pressure (mmHg)	11	10	10	10	10
O2 Sat	99	100	100	100	100
SpO2 (Second)					
Heart Rate	86	94	90	92	91
Patient Temperature C(F)					
ECLS Pump					
Out/ART Flow (L/min)	0.4	0.48	0.48	0.49	0.49
In/VEN Flow (L/min)	1.56	1.63	1.64	1.65	1.65
Cardiac Index (mL/kg/min)	80	95.8	97	98.5	98.5
Cardiac Index (L/m2/min)	1.3	1.6	1.6	1.6	1.6
Console Flow	1.31	1.37	1.37	1.39	1.38
Console Speed RPM	2345	2345	2345	2345	2345
Oxygenator Settings					
Membrane O2%	40	40	40	40	40
FiCO2%	0	0	0	0	0
Membrane O2 L/min	0.55	0.55	0.55	0.55	0.55
System Pressures					
In/VEN Line (mmHg)	-27	-35	-35	-34	-34
Premembrane (mmHg)	129	122	122	122	122
Out/ART Line (postmembrane) (mmHg)	121	113	113	114	114
Delta P mmHg	8	8	8	9	8
System Temperatures					
Out/ART Line (postmembrane) C(F)	36.6 (97.9)	36.6 (97.9)	36.5 (97.7)	36.6 (97.9)	36.5 (97.7)
Systemic Water Bath C(F)	37 (98.6)	37 (98.6)	37 (98.6)	37 (98.6)	37 (98.6)

Figure 5. Periodic documentation.

Before our VIPER to Epic discrete data integration, the documentation standard for the ECMO team was hourly as is the case in many institutions. Although more frequent manual documentation may be impractical, hourly documentation gives little insight in to the previous hour's events and documentation during emergencies is often insufficient to determine what happened leading up to and during an event. Manual documentation of over 20 parameters takes attention away from the patient and allows for manual data entry errors. After the integration, manual recording of these parameters is no longer necessary and the potential for data entry errors is virtually eliminated. In addition, automated data collection during emergencies is maintained while the clinician is managing the circuit and the patient.

Data and information are timestamped to the second in VIPER. This presented an issue when transferring the information to Epic. Although data can be documented by the second in Epic, our institutional practice is to document by the minute. To accommodate this practice, events and comments documented in VIPER within the same minute are combined and separated with brackets { } (Figure 6). Parameters for a given minute are taken from the minute and zero second timestamp in VIPER.

Downtime documentation processes are necessary in the realm of electronic documentation. Expected downtime operations including Epic updates and unexpected downtime events, including network outages, all require processes to ensure ongoing documentation. Using the type of integration described, our system provides an additional layer of security. During Epic downtimes or any occurrence that may interrupt the VIPER to Epic connection, VIPER continues to record all parameters and events in real time. Messages are queued and transmitted to Epic when communication is restored. If the VIPER system goes down, manual documentation is still available in Epic. In the event of



	12/21/16					
	1510	1511	1513	1515	1516	1517
Mechanical Assist Device						
Mechanical Circulatory Support						
ECLS						
CPB Time						
Cross Clamp Time						
Donor Organ Ischemic Time						
Circulatory Arrest Time						
Cerebral Perfusion Time						
Events						
Event	Note {}	Washed PRBC...	Sodium Bicarb...	Vecuronium (m...	Plasma-Lyte A...	P
Comment	VIPER powere...	=W037716068...	{}	per Anesthesia...	{}	
ECLS Vitals						
Systolic Blood Pressure (mmHg)		32	30			31
Diastolic Blood Pressure (mmHg)		32	30			31
Mean Blood Pressure (mmHg)		32	30			31
Central Venous Pressure (mmHg)						
Heart Rate (BPM)		53	70	87	96	102
Patient Temperature C(F)		22.5	22.8	23.3	23.6	24
ECLS Pump						
Out/ART Flow (L/min)		0.69	0.69	0.69	0.69	0.69

Figure 6. Events and comments separated with brackets { }.

a simultaneous failure of both systems, paper documentation is still available. In addition, more an offline rather than downtime procedure, when a patient is transported all available data continue to be collected during the transport by the VIPER. If using Wi-Fi, the data continues to be transmitted to Epic. If using a wired network connection or out of Wi-Fi range, the data is transferred when a connection is reestablished. The ability of this system to acquire and store data when offline is a significant advantage that allows documentation consistency regardless of the location of care; ICU, catheterization lab, operating room, or inter/intrahospital transport.

The VIPER system has the capability of receiving lab values from point of care (POC) devices via direct connection. Although this is a capability of other third party perfusion EMRs, there is some limitation to direct connection integration. Pertinent labs resulted in the core lab as well as those run on some handheld POC devices are not captured by the device without manual documentation. In addition, during procedures in other areas of the institution or transports with ECMO patients, the direct connections may not be available. To capture all relevant core lab generated values and POC device results, an interface was developed to transfer lab values generated during a CPB or ECMO run from the lab server to VISION. These values are sent from VISION to the appropriate VIPER EMR based on matching demographic data. The values in Table 2 are those we chose to have retained in the VISION database with the rest of the clinical data. Other values may be added or removed from this list when the interface is developed.

Riley suggests the ideal perfusion data acquisition model collects and makes available in real time the appropriate variables, alerts clinicians to a variation in optimal parameters, populates a database for quality monitoring and

Table 2. Lab values collected via the lab server/VISION interface.

pH	pCO_2	pO_2	sO_2 (%)
Hct (%)	tHb (g/dL)	MetHb (%)	COHb (%)
Lac (mmol/L)	Glu (mg/dL)	K^+ (mmol/L)	Na^+ (mmol/L)
Ca^{2+} (mmol/L)	HCO_3 (mmol/L)	cBase(B) (mmol/L)	Plasma Free Hgb
INR	PT	aPTT	Unfractionated heparin
Chloride	Creatinine	Anion gap	BUN
B/C ratio	Platelets	Fibrinogen	AT3
HPT patient heparin concentration (u/mL)	HDR projected heparin concentration (u/mL)	HDR slope	ACT

research, and has the capability of passing de-identified data to national registries (3). We could not agree more and with the merger of these two systems we believe we have accomplished each of these goals.

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