The Power Of Instant Data
In The Clinical Arena

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One of the interesting and unanticipated early effects of the National Heart Attack Alert Program of the last decade was that it forced people to look closely at the internal processes that determine how a patient receives care in the emergency department.

One of the revelations in our own department was that our biggest delay in time-to-treatment came from something very simple. In our department, the EKG was performed by a tech who came from outside the department. When the EKG was completed, it was placed either in a basket full of other EKG tracings, or on the inside of the chart, which was buried back in the chart rack. An EKG was only seen when the attending physician came out and asked "where is the EKG for the patient in room 4?" The delay evaporated when we required that each EKG be handed directly to the attending physician, but it seemed strange that so important a bottleneck could have gone unrecognized for so many years.

We began to realize that reducing time-to-treatment for patients with acute MI is just a special case of the general problem of reducing time-to-treatment for all patients. In fact, most patients are more concerned with our "door-to-door" time than they are with our "door-to-drug" time.

We began to build simple models to help us understand patient flow in the ED. Early on we recognized that patient flow is highly dependent on a long series of sequential processes, any one of which can become a bottleneck for the overall flow of patients through the department. The sad truth is that most patients spend most of their time waiting for something. Even worse: at any given moment, most of the patients who are in the emergency department are there ONLY because they are waiting for something.

If we model the Emergency Department from a patient's viewpoint, it looks something like figure 1.

Figure 1. The Emergency Department as seen by a patient.

- Arrive
  - Wait for registration
- Register
  - Wait for triage
- Get triaged
  - Wait for physician
- See physician
  - Wait for physician to write orders
  - Wait for clerk to pick up orders
  - Wait for requests for prior records, EKG, x-rays
  - Wait for nurse to pick up orders
  - Wait for EKG tech to arrive
- Have EKG
  - Wait for nurse to arrive to draw blood
- Have blood drawn
  - Wait for transport to x-ray
  - Wait in hallway outside x-ray
- Have X-ray
  - Wait for films to be developed
  - Wait for transport back to ED
  - Wait for x-ray to come back
  - Wait for physician to notice x-ray
  - Wait for lab results to come back (16 steps)
  - Wait for physician to notice lab results
  - Wait for old x-rays to come back
  - Wait for physician to notice old x-rays
  - Wait for old EKG to come back
  - Wait for physician to notice old EKG
  - Wait for old ER charts to come back
  - Wait for physician to notice old ER chart
  - Wait for old medical records to be found
  - Wait for physician to notice old charts
  - Wait for physician to notice any lapses
- See physician
  - Wait for any further (or repeated) labs, etc.
  - Wait for physician to notice and review results
  - Wait for physician to make decisions
  - Wait for call to PMD
  - Wait for disposition orders
  - Wait for nurse to pick up orders
  - Wait for nurse to prepare discharge
- Get Discharged

The entire process is cumbersome even when things go smoothly, and it deteriorates rapidly under even minimal stress. Common, simple problems can add many hours to the total ED time of patients. For example, a patient can wait several extra hours if the blood is hemolysed, or there is too much noise in the EKG, or the old records cannot be found, or the clerk forgets to page the PMD, or the PMD calls back only to be put on permanent hold.

In many cases the experience is unsatisfying for all concerned. Patients feel they've been neglected and abandoned, while from the point of view of the physician, caring for patients in the emergency department often resembles nothing so much as a complicated scavenger hunt. The entire system is fundamentally broken in several different ways.

- Too many processes occur serially, rather than in parallel. When a point-failure is noticed and corrected, all the subsequent processes are still waiting to be carried forward.
- There is no local feedback built into any of the sequential processes. Failures are noticed only when somebody happens to think of it and decides to check on the progress of an order or a test.
- The result of each process is found in a different place, by a different method of inquiry. The methods of inquiry often may be arcane and undocumented. Sometimes, even finding out whether something has gone wrong requires secret knowledge or the assistance of the high priestess who holds the key to the ancient mysteries.

As we tried to fix the problem, we began looking at ways to merge or eliminate many of the potential waiting states, ways to create local feedback loops to prevent unrecognized breakdowns, and ways to make the entire process and all the results visible on a single computer screen. As it turned out, many of the problems could be addressed with a single unified approach.

Many of the processes that require waiting (and much of a patient's waiting time) arise from problems with the availability of existing medical information. The gathering and communication of medical information is a fragmented, hit-or-miss process that involves repeated interactions with many other departments. Physicians, nurses, and ancillary staff spend an inordinate amount of time hunting and gathering clinical information that comes from the current visit and from prior visits to the institution (see figure 2).

Figure 2. Typical ED information needs

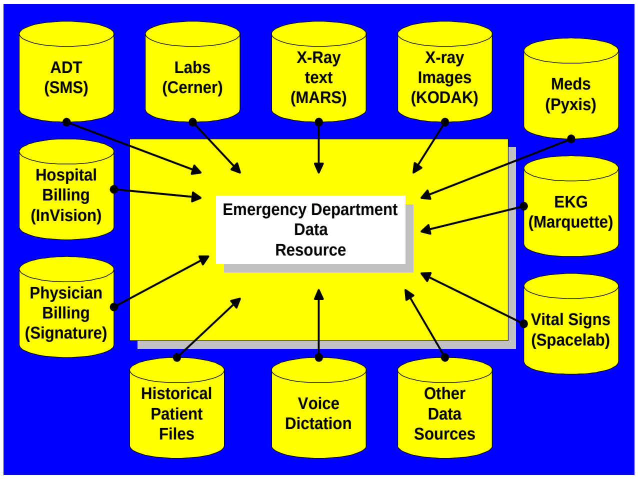
Current visit
- lab orders
- lab results
- x-ray orders
- x-ray results
- x-ray images
- EKG images
- Medications given
- procedure orders
- procedure results

Prior visits
- lab results
- x-ray results
- x-ray images
- medication history
- procedure results
- EKG results
- EKG images
- inpatient diagnoses
- outpatient diagnoses
- dictated summaries
- ED charts

In an effort to move beyond the "hunter-gatherer" era of medical information, we developed the concept of a "ED traffic control" system that would bring together as many different types of information as possible into a single place, store the information for later re-use, and display all the information in a consistent way that would be easily accessible to the emergency physician. Instead of hunter-gatherers, we would become "information farmers," responsible for our own crop of medical information.

To achieve this, we built interfaces that accept data from a variety of legacy, or "smokestack" systems. Hospital computers send their data in proprietary formats to an interface engine, which translates the data into an industry-standard format called "Health Level Seven" (HL7). The translated data is sent to an emergency department interface engine, and then is loaded into a standard, off-the-shelf database that uses a standard "structured query language" (SQL). Nearly all of the data comes to us within a few seconds after it is generated in the hospital mainframes, so any delays after that point are within our direct control. We receive data from many different hospital computers, including those that handle registration, labs, radiology results, radiology images, pharmacy, prior diagnoses, prior procedures, dictations, billing, materials management, infection control, and historical files. (see figure 3).

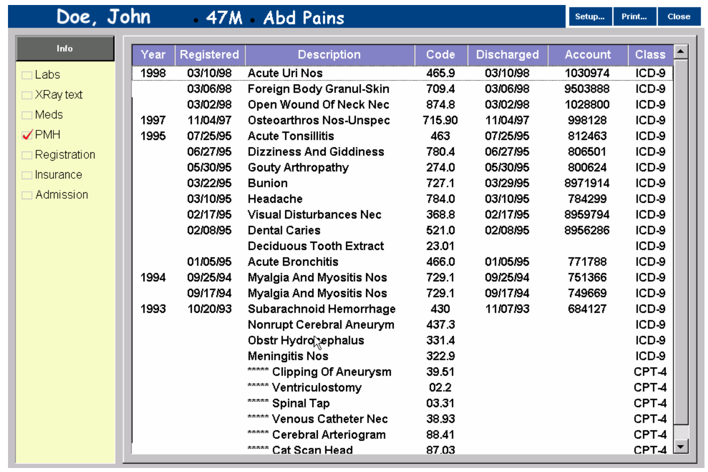
Figure 3. Many different sources of information all brought together at the same time and place.



The entire system is built in a highly modular fashion using open standards and off-the-shelf components. It is quite simple to add new data elements as they become available, and this has become an ongoing process. New data elements that are currently being added include patient vital signs (acquired automatically from Spacelabs™ monitors) and patient and staff location (tracked automatically using the PinPoint™ radio-frequency locator system). We have experimented with a variety of special-purpose equipment, including fingerprint sensors, iris scanners, and voice recognition systems.

The system as described has been operational since December 1996, and had a tremendous impact on the quality and efficiency of practice. Our practice environment has been transformed because instead of seeking out information in a variety of formats from a large number of different sources, we can find nearly anything desired in a single place, using a single simple interface. For example, within just a few months, we found that we rarely needed to send for old records, because most of the historical information we wanted was already in our own system. We can find prior diagnoses and lab and x-ray results for most of our repeat patients, because we have been receiving those results for every patient visit since early 1997. We have all the data from every prior ED visit since that time, and we have also been able to load historical patient files that give us all prior inpatient and outpatient diagnoses dating back to 1992 (see figure 4).

Figure 4. All the patient's prior diagnoses and procedures are available with a single click.



Year	Registered	Description	Code	Discharged	Account	Class
1998	03/10/98	Acute Uri Nos	465.9	03/10/98	1030974	ICD-9
	03/06/98	Foreign Body Granul-Skin	709.4	03/06/98	9503888	ICD-9
	03/02/98	Open Wound Of Neck Nec	874.8	03/02/98	1028800	ICD-9
1997	11/04/97	Osteoarthros Nos-Unspec	715.90	11/04/97	998128	ICD-9
1995	07/25/95	Acute Tonsillitis	463	07/25/95	812463	ICD-9
	06/27/95	Dizziness And Giddiness	780.4	06/27/95	806501	ICD-9
	05/30/95	Gouty Arthropathy	274.0	05/30/95	800624	ICD-9
	03/22/95	Bunion	727.1	03/29/95	8971914	ICD-9
	03/10/95	Headache	784.0	03/10/95	784299	ICD-9
	02/17/95	Visual Disturbances Nec	368.8	02/17/95	8959794	ICD-9
	02/08/95	Dental Caries	521.0	02/08/95	8956286	ICD-9
		Deciduous Tooth Extract	23.01			ICD-9
	01/05/95	Acute Bronchitis	466.0	01/05/95	771788	ICD-9
1994	09/25/94	Myalgia And Myositis Nos	729.1	09/25/94	751366	ICD-9
	09/17/94	Myalgia And Myositis Nos	729.1	09/17/94	749669	ICD-9
1993	10/20/93	Subarachnoid Hemorrhage	430	11/07/93	684127	ICD-9
		Nonrupt Cerebral Aneurym	437.3			ICD-9
		Obstr Hydrocephalus	331.4			ICD-9
		Meningitis Nos	322.9			ICD-9
		***** Clipping Of Aneurysm	39.51			CPT-4
		***** Ventriculostomy	02.2			CPT-4
		***** Spinal Tap	03.31			CPT-4
		***** Venous Catheter Nec	38.93			CPT-4
		***** Cerebral Arteriogram	88.41			CPT-4
		***** Cat Scan Head	87.03			CPT-4

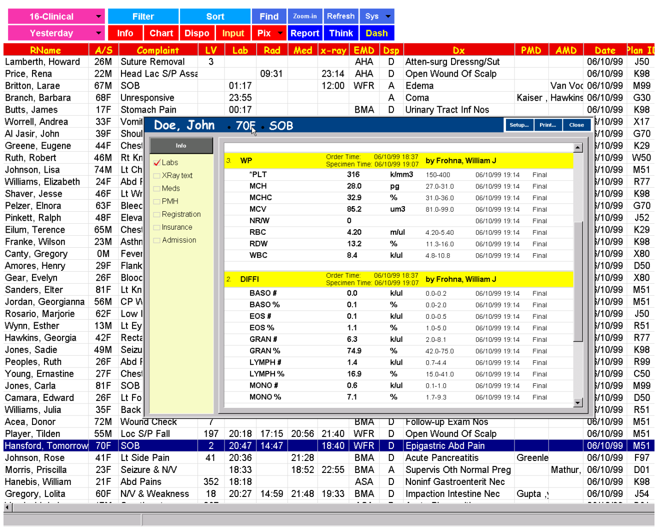
Our data storage needs are fairly large, because we store x-ray and other images that can be enormous. Despite the size of these image files, we believe we will be able to keep all the data on-line indefinitely, because we add new patients at a linear rate, while hard disk storage gets bigger, faster, and cheaper at a logarithmic rate.

We use a variety of programs to work with all the data we have received. The most widely used program is one we wrote ourselves, called "InSight." InSight is built around the principle that as much information as possible should be visible, all at one time and all in the same place. The main screen of InSight is a grid that shows a row of information about each member of a cohort of patients. The default cohort is all the patients who are presently in the emergency department, but the user can easily choose to see all the patients from any day or group of days, or to see all the patients for any range of dates who meet any arbitrary filtering criteria based on any information field we possess. For example, it is trivially easy to look at all patients seen in the last 2 weeks with chest pain, or all of the patients seen by a particular doctor within the past 3 months, or all of the patients admitted to the ICU over the weekend.

For any particular patient in the cohort, the grid row contains many different information elements. The list of information elements can be customized on-the-fly to include any of the several thousand different fields of information that we possess for each patient. Most clinical users choose to display patient identifiers, the complaint, and the time of the most recent labs, medications, x-ray readings, and images, together with the name of the PMD, the type of insurance, and a few other fields of general interest. Outside the immediate clinical area, people often work with displays they have customized to include a completely different list of fields. Any user-created customization can be saved with its filters and date scopes as a "named view" that can be recalled at any time.

The entire system has a very "flat" design, so that nearly all the information that exists about any patient can be found within one click from the main screen. It is impossible to get lost within cascading menus, because there simply aren't any. Menus include at most one layer of choices, and most desired information can be reached by clicking on a grid cell to get more information. For example, a grid cell that shows the time of the most recent lab results can be clicked to see the actual lab results in a pop-up window (see figure 5).

Figure 5. Lab results in a pop-up window



When the first wireless palmtop devices began to appear, we recognized the possibility that instant wireless access to these data elements might be useful to some clinical and administrative users. We undertook extensive experimentation with a variety of systems, including rolling kiosks containing a full-scale desktop computer, smaller rolling stands with a laptop computer, "clipboard" or "tablet" computers, small pocket computers with flip-down keyboard, and finally PDA-format palmtop devices. To our surprise, the PDA format was a clear winner despite the small screen size and lack of a keyboard. Today, clinicians can review clinical data using a wireless PDA while strolling the hallways or dining in the cafeteria – browsing through real-time lab results, dictations, prior diagnoses, medications, x-ray results, and even x-ray images.

In developing this system we have gone against traditional wisdom in several ways.

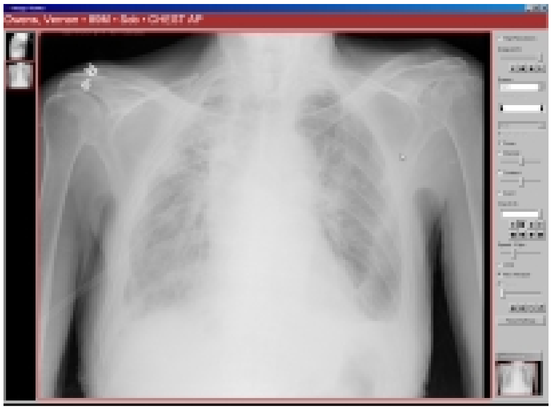
Conventional wisdom says "buy, don't build." We disagree. In today's world, proprietary systems become obsolete long before the last payment is made. We think the right answer today is "buy AND build." Buy industry-standard off-the-shelf hardware and software, and meet specific needs by building small modules that can get and show information using open standards for data communication. Upgrade everything constantly, piece by piece, so that nothing becomes so obsolete as to become a millstone around the neck of progress.

Conventional wisdom says "get everybody involved from the beginning." We disagree. In a free society, people seem to feel it is their duty to have an opinion about everything, yet in the design of computer systems, uninformed opinions are at best a distraction. Some of the greatest projects have foundered under the weight of the involvement of interested but unqualified stakeholders. The right approach is to have a very small number of highly qualified people involved.

Conventional wisdom says "plan for every contingency." We disagree. In a complex system, it is impossible to know what will happen when a new set of variables are introduced. Most planning efforts are wasted on contingencies will never come to pass. It is better to plan for the anticipated outcome, and to maintain an agile readiness to make changes rapidly to meet unforeseen contingencies.

Conventional wisdom says "invest heavily in training." We disagree. If ordinary use of a clinical computer system requires more than 30 seconds of training, the system is a failure and should never be installed in the first place. In our environment, we put a computer into the clinical area with a sign saying that the system was in beta-test, and that clinicians were not authorized to use it. We gave two people each a 30-second demonstration of how they might make "unauthorized" use of the system. Two weeks later, the system was in widespread use. Today, there isn't a nurse in the ED who doesn't use the system freely for a variety of purposes, and there isn't a resident in the institution who doesn't use the system to look up labs, X-rays, and other information on their patients. Granted, there is much, much more to the system than is seen by casual users, but even the most advanced uses of the system can be mastered after a single demonstration lasting no more than a couple of minutes, followed by a little experimentation.

Figure 6. X-ray images with a single click



A few moments with the system suffice to show how easily (with one or two clicks) we are able to answer a series of common questions, and how powerful it can be to have instant access to information in the clinical arena. Almost as important is the impact on clinical research and on the management and administration of an emergency department. Novice users can easily explore questions such as the following.

<u>For a single patient:</u>

- What lab results are back?
- What is the x-ray reading?
- Can I see the x-ray image? (figure 6)
- Can I see the old paper chart? (figure 7)
- What medications have been given? (figure 8)
- When was the last visit to our ED?
- What were the labs or x-rays at a prior visit?
- What diagnoses and procedures are in the past medical history?

<u>For a cohort of patients:</u>

- How many patients are in the department?
- Which patients have not yet been fully registered?
- How many patients have we seen so far today?
- Are we above or below average so far?
- What was the busiest day of the past year?
- How many pregnant teens have we seen this year? (figure 9)
- Show all the elevated glucose results for all patients this week.
- Show all patients who received fentanyl during the past 2 years.

Figure 7. Scanned paper chart for a prior visit

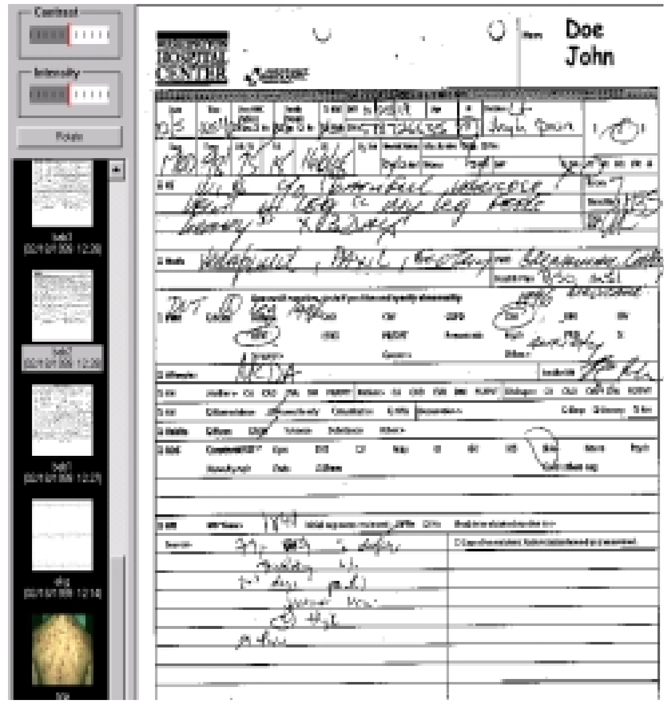


Figure 8. Medications in a popup window

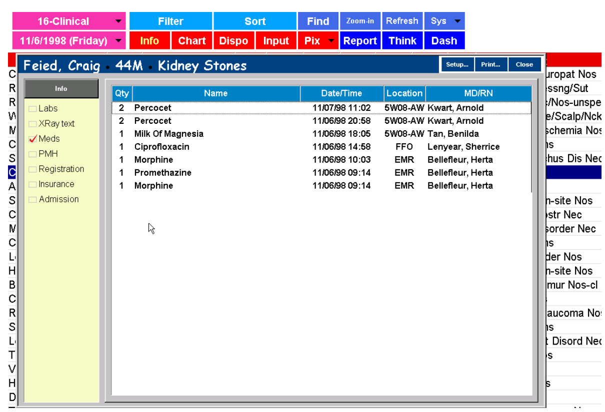
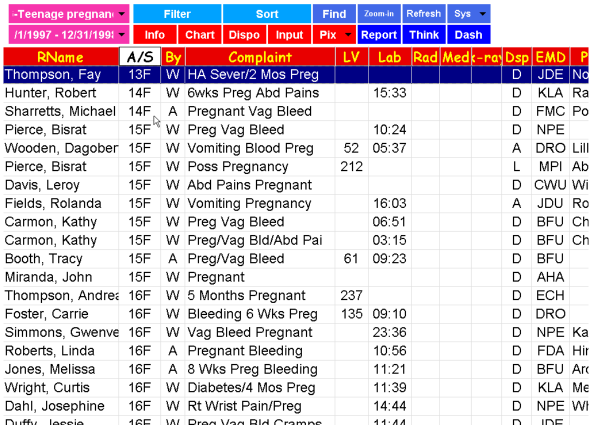


Figure 9. Pregnant teen patients during 1997 – 1998



RName	A/S	By	Complaint	LV	Lab	Rad	Med	-ray	Dsp	EMD	P
Thompson, Fay	13F	W	HA Sever/2 Mos Preg						D	JDE	No
Hunter, Robert	14F	W	6wks Preg Abd Pains		15:33				D	KLA	Ra
Sharretts, Michael	14F	A	Pregnant Vag Bleed						D	FMC	Po
Pierce, Bisrat	15F	W	Preg Vag Bleed		10:24				D	NPE	
Wooden, Dagober	15F	W	Vomiting Blood Preg	52	05:37				A	DRO	Lill
Pierce, Bisrat	15F	W	Poss Pregnancy	212					L	MPI	Ab
Davis, Leroy	15F	W	Abd Pains Pregnant						D	CWU	Wi
Fields, Rolanda	15F	W	Vomiting Pregnancy		16:03				A	JDU	Ro
Carmon, Kathy	15F	W	Preg Vag Bleed		06:51				D	BFU	Ch
Carmon, Kathy	15F	W	Preg/Vag Bld/Abd Pai		03:15				D	BFU	Ch
Booth, Tracy	15F	A	Preg/Vag Bleed	61	09:23				D	BFU	
Miranda, John	15F	W	Pregnant						D	AHA	
Thompson, Andrea	16F	W	5 Months Pregnant	237					D	ECH	
Foster, Carrie	16F	W	Bleeding 6 Wks Preg	135	09:10				D	DRO	
Simmons, Gwenve	16F	W	Vag Bleed Pregnant		23:36				D	NPE	Ka
Roberts, Linda	16F	A	Pregnant Bleeding		10:56				D	FDA	Hir
Jones, Melissa	16F	A	8 Wks Preg Bleeding		11:21				D	BFU	Arc
Wright, Curtis	16F	W	Diabetes/4 Mos Preg		11:39				D	KLA	Me
Dahl, Josephine	16F	W	Rt Wrist Pain/Preg		14:44				D	NPE	Wl
Duffy, Jessie	16F	W	Preg Vag Bld Cramps		11:44				D	JDE	

Although there are many other reasons why patients may have to wait in the emergency department, in our experience prolonged waits while clinicians seek out existing medical information can be all but eliminated. The tool with which to accomplish this is a central departmental data resource that makes use of open standards to receive, store, and re-display existing clinical information.

We believe the power and impact of instant access to data in the clinical arena can hardly be overstated. In 1996 we came to an emergency department that had seen 37,000 patients per year and was ranked worst in the region in a Gallup poll. A few years later our volume has risen to 67,000 patients per year and we have been ranked #1 in the Gallup poll. Instant data is one of the secret weapons that helped us get there.