Cleveland Clinic

RSNA 2024
Building Intelligent Connections

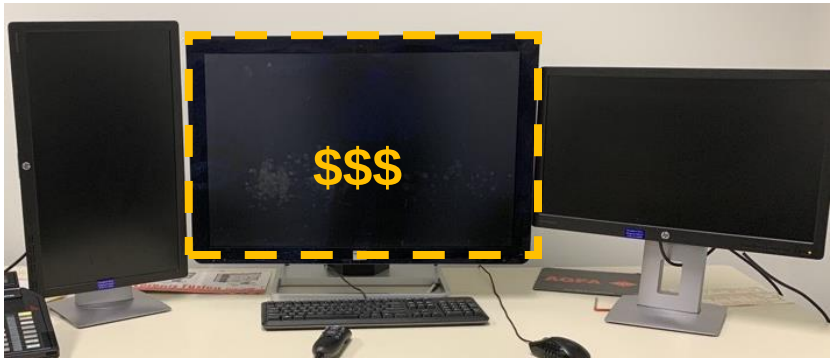
Dollars and Displays: An activity-based costing approach to assessing the total cost of ownership of commercial-grade displays versus diagnostic-grade displays for remote diagnostic stations

Katie Hulme[1], Jen Arnold[1], Ryan Thomas[1], Namita Gandhi[1], Roy Kittelberger[1], Massai McDaniel[1], Jason Massey[1], Douglas Nachand[1], Monica Sanchez[1], Po-Hao Chen[1]

[1]*Cleveland Clinic*

Introduction

- Increasing demand for remote-friendly work
- Workstations with **Commercial-grade** Displays (**WCDs**) promise cost savings over workstations with **Diagnostic-grade** Displays (**WDD**)
- Which one has a lower total cost of ownership (TCO), not just cheaper upfront cost? Sources of added TCO include:
  - Manual display quality control (QC)
  - Nuanced deployment strategy by radiology IT
  - Maintenance and reliability of equipment
- TCO was calculated by combining initial equipment acquisition cost with an activity-based costing (ABC) approach for ongoing recurring costs



Workstation with Diagnostic-Grade Display (WDD)

VS.

Workstation with Consumer-Grade Display (WCD)

Methods

- Initial experience deploying 62 workstations with **Commercial-grade** displays (**WCD**) used to quantify soft-costs and inform decisions regarding future setups for remote workstations

ASSESSMENT OF TOTAL COST OF OWNERSHIP (TCO)

2022 — 2023 — 2024

PILOT STUDY

Workstation with Commercial-grade display (WCD) selected for pilot:

- Achieved ~50% initial cost savings per radiologist workstation relative to the institution's current Workstations with Diagnostic-grade Displays (WDD)
- Met the specifications for diagnostic (non-mammo) displays outlined in the 2022 ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging
- Was found to be sufficiently stable to be used for non-mammography interpretation
- BUT required routine manual calibration to maintain compliance with DICOM Greyscale Standard Display Function

Hulme K., Thomas R., Nachand D., Gandhi N., Chen P., Let's Not "Plug and Pray" – Long Term Tradeoffs of Consumer-Grade, Presented at RSNA, Chicago, IL, November 28, 2022

WCD ROGRAM DEVELOPMENT

Processes and documentation established for:

- Workstation assembly
- Radiologist attestation and questionnaire (required to receive home station)
- QC software installation and configuration
- Instructions for monthly radiologist QC
- Acceptance testing procedure and template
- Deployment workflow and time tracker

REMOTE WORKSTATION DEPLOYMENT

Full-time remote radiologists received WDD, all others received WCD

Total of 62 WCD deployed:

- 2023 Q4 – 3
- 2024 Q1 – 18
- 2024 Q2 – 12
- 2024 Q3 – 29

Time sheets maintained by IT analysts during deployment of initial 29 WCD

Total of 16 WDD deployed:

- 2023 Q4 – 2
- 2024 Q1 – 5
- 2024 Q2 – 4
- 2024 Q3 – 5

Stations deployed to new hires (full-time remote only)

Direct Costs

- Equipment accounted for once as initial purchase cost
- Listed costs were based on average of various manufacturer's suggested retail prices (MSRP), where applicable
- Identical workstation builds (including graphics card) were assumed for all setups

Workstation utilizing a high-quality **Commercial-grade** display (meeting the specifications of the 2022 ACR-AAPM-SIIM Technical Standard)

Workstation utilizing a "High-End" 6MP **Diagnostic-grade** display

Workstation utilizing newly-available "Mid-Level" 8MP **Diagnostic-grade** display

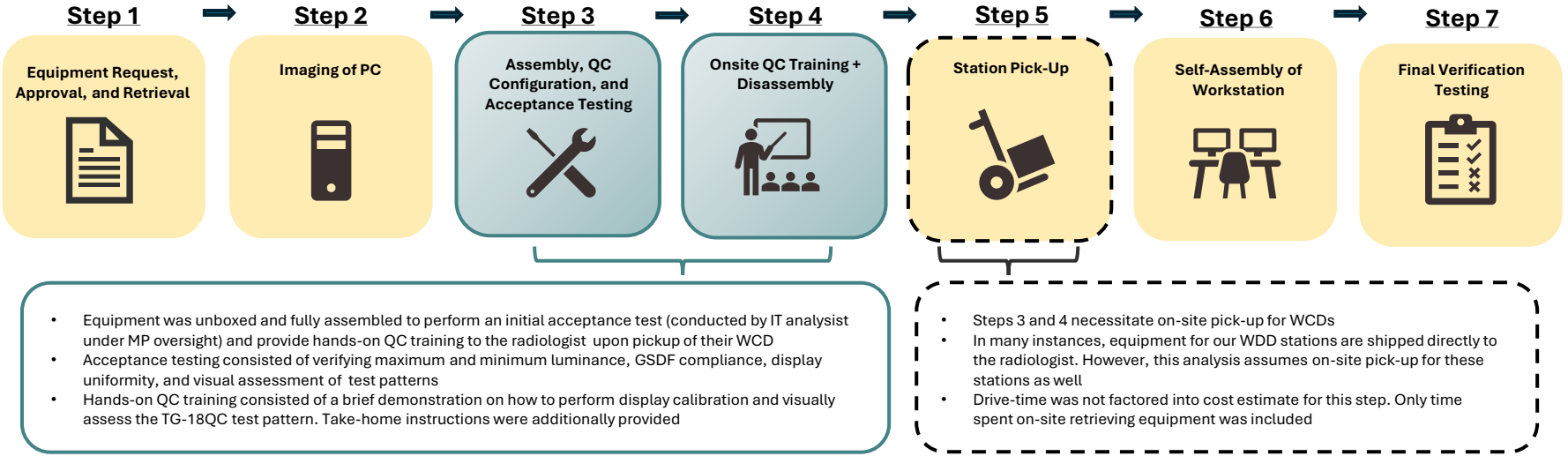
DIRECT COSTS:	WCD	WDD "High-End" 6MP		WDD "Mid-Level" 8MP	
	MSRP av	*MSRP av*	*MSRP min*	*MSRP av*	*MSRP min*
Workstation					
Tower, Graphics Card, Processor, etc.	$ 3,200	$ 3,200	$ 3,200	$ 3,200	$ 3,200
Peripheral Equipment					
List Displays, Speech Mic, Networking Solutions, etc.	$ 1,730	$ 1,730	$ 1,730	$ 1,730	$ 1,730
Diagnostic Display	***$ 1,155***	***$ 11,601***	***$ 7,250***	***$ 5,582***	***$ 3,200***
QC Software License + Photometer	$ 1,280	--	--	--	--
	$ 7,365	**$ 16,531**	**$ 12,180**	**$ 10,512**	**$ 8,130**

- WCDs require the additional purchase of a photometer and third-party software for calibrating the display to the DICOM Greyscale Standard Display Function (GSDF)
- Diagnostic-grade displays generally have built-in photometers, and the cost of the photometer and calibration software are included in the cost of the monitor

- Use of a commercial-grade display can reduce the upfront cost of a workstation by ~55% relative to a standard diagnostic-grade 6MP
- Some vendors now offer diagnostic-grade 8MPs at a more competitive price-point. These displays have less powerful backlights (compared to 6MPs) but have built-in photometers and are capable of self-calibration.

Indirect Costs: Deployment

- Our institutional deployment process for WCDs consisted of 14 distinct activities, which were then categorized into 7 general steps Activities in **BLUE** are unique to workstations with **Commercial-grade** displays (**WCD**)
- Average, min, and max time for each step were calculated from time sheets maintained by IT analysists during the deployment of 29 WCD



Indirect Costs: Deployment

- This table presents the data for the average time spent on each deployment step, the responsible party, and the estimated cost

National estimates of mean hourly wages, as reported by the U.S. Bureau of Labor Statistics (bls.gov), were assumed when calculating activity-based costs.

Occupation	Mean Hourly Wage
IT Analyst	$ 53.27
Medical Physicist	$ 104.18
Radiologist	$ 170.17

Because workstations with Commercial-grade displays (WCDs) necessitated stations be built in full the purposes of calibration, acceptance testing, and radiologist QC training, and then disassembled for distribution, **overall deployment activities were estimated to add an additional $784, on average, to the TCO for WCD, compared to $348 for workstations with Diagnostic-grade displays (WDD).**

INDIRECT COSTS: DEPLOYMENT (per workstation)	Party	WCD Av. Time (min)	WCD Estimated Cost	WDD Av. Time (min)	WDD Estimated Cost
Equipment Request, Approval, Retrieval	IT Analyst	106	$ 94	106	$ 94
Imaging of PC	IT Analyst	83	$ 74	83	$ 74
Assembly, QC Config, Acceptance Testi	IT Analyst	145	$ 129	0	$ -
Onsite QC Training + Disassembly	IT Analyst	50	$ 44	0	$ -
	Radiologist	50	$ 142	0	$ -
Station Pick-Up	IT Analyst	37	$ 33	12	$ 11
	Radiologist	37	$ 104	12	$ 34
Self-Assembly of Workstation	Radiologist	50	$ 142	40	$ 113
Final Verification Testing	IT Analyst	25	$ 22	25	$ 22
			$ 784		$ 348

Indirect Costs: Ongoing

- Incremental yearly costs were broken down into 4 distinct activities. Activities in **BLUE** are unique to workstations with **Commercial-grade** displays (**WCD**):

Quality Control (Manual QC - WCD)

- Display calibration (~10 minutes)
- Visual assessment of test pattern (<1 minute)
- Responsibility of the radiologist to initiate, complete, and verify all items in compliance

RADIOLOGIST

- Unlike WDDs, which can run scheduled QC tasks without user intervention, WCD require the use of an external photometer and user-initiation to accomplish these tasks
- Our institution required QC to be performed on a MONTHLY basis

IT Support/Troubleshooting (General)

Respond to calls related to:

- Network connectivity
- Hardware
- Software installation, access, and functionality (PACS, RIS, specialty software, etc.)
- Updates (for OS, software, etc.)

IT ANALYST

- Calls received by the Radiology IT Help Desk that are specific to the calibration of WCD are escalated to WCD subject matter experts (a subset of IT analysts)

IT Support/Troubleshooting (Manual QC - WCD)

Respond to calls related to:

- Display calibration failures
- Display QC software issues (configuration, settings, license, etc.)

IT ANALYST

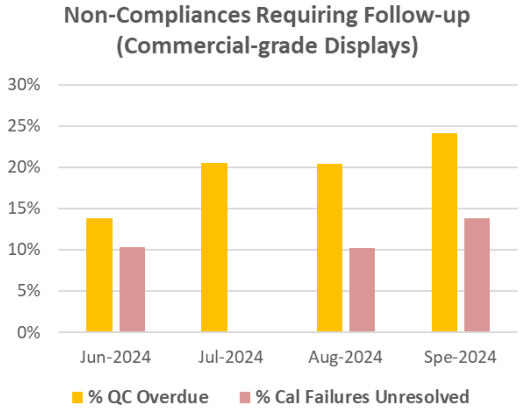
QC Oversight (Manual QC - WCD)

- Develop QC processes and documentation for IT analysts and radiologists
- Identify and follow-up on non-compliances (i.e. QC not being performed, unaddressed QC failures)

WCD QA TEAM

- A team consisting of IT analysts (WCD subject matter experts), a Medical Physicist, and the Chief Informatics Officer was established
- WCD QA Team met on a weekly basis during the initial 6 months of WCD deployments

Indirect Costs: Ongoing



	GSDF Compliance - Failure Rate	GSDF Compliance - Av. Max Deviation	White Point
Diagnostic-Grade Display (n=36)	1%	3%	Excellent
Consumer-Grade Display (n=52)	20%	11%	Good

- # stations flagged for user-initiated QC not being performed increased from ~14-24% over 4 months, as both number of deployed stations and length of deployment increased
- In 10-15% of cases, failures encountered during routine QC were not initially identified and remedied with subsequent calibration by the user
- Frequency of non-compliances and time required to manually follow-up with radiologists has necessitated process improvements, including improved documentation and communication, as well as implementation of automated emails (with assistance from in-house developers)

- QC test histories were exported for analysis from 88 remote workstations (52 WCD, 36 WDD)
- WCD had been deployed for 128 days, on average, with an average of 16 data points per workstation
- WDD had been deployed for 200 days, on average, with an average of 29 data points per workstation
- Failures in GSDF compliance occurred approximately 20% of the time for WCD, compared to 1% for WDD
- Maximum absolute deviation from GSDF was ~11% for WCD, on average, compared with 3% for WDD
    - It is recommended the maximum deviation be maintained at <10% for displays used for diagnostic interpretation
- Backlight of the selected display for WCD has been sufficiently stable over the evaluated time frame (av. 128 days, max 367 days)

Indirect Costs: Ongoing

- Activity-cost for yearly maintenance on WCD depends on:
  - Frequency of manual QC (calibration, etc.)
  - Frequency of QC failures and degree of difficulty in troubleshooting
  - Time required to track and enforce routine user-initiated QC
- Table below assumes QC for WCD is performed monthly with a 20% failure rate (requiring repeated display calibration)
- Preliminary experience (~1 year) was used to inform estimates, however, additional experience and data may result in adjustments

Limitations

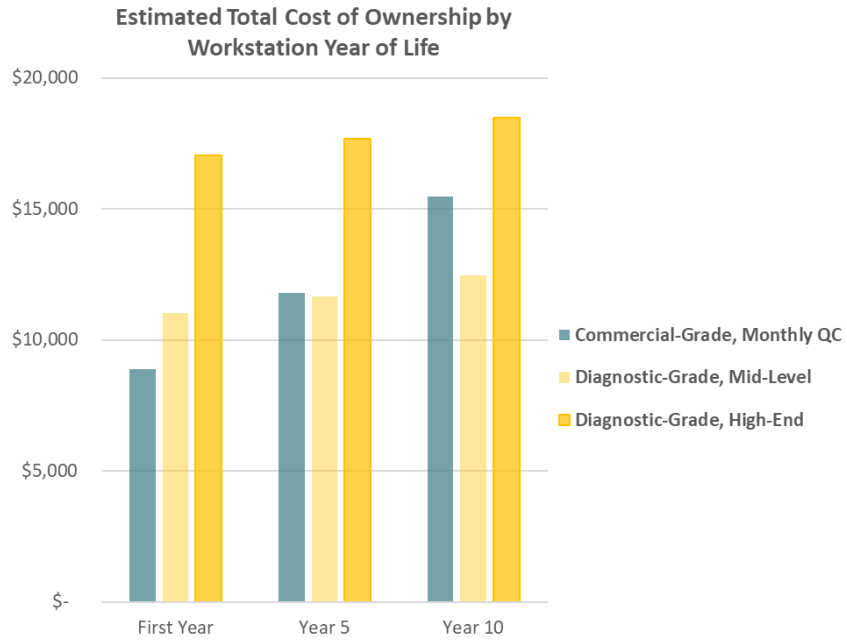
- TCO estimates in this study did not account for monitor replacement. Warranties for consumer-grade displays generally do not cover GSDF compliance (unlike the typical 5-year warranties for many diagnostic-grade displays) and may not guarantee the desired white point for calibration over the lifetime of the display.
- Only costs directly related to individual workstations were considered. Programmatic costs affiliated with WCD use (server setup, process development, training, etc.) were not accounted for in TCO estimates, though these costs are also non-negligible.

The activity-cost for yearly maintenance was ~$732 for WCD, compared to ~$160 for WDD. The major contributing drivers for WCD's higher yearly activity cost were manual QC and calibration, IT support for QC failures, and physicist oversight related to QC.

INDIRECT COSTS: ONGOING (ANNUAL) (per workstation per year) QC Frequency = MONTHLY	Party	WCD Av. Time (min)	WCD Estimated Cost	WDD Av. Time (min)	WDD Estimated Cost
Quality Control (Manual)	Radiologist	144	$ 408	0	$ -
IT Support - Troubleshooting - General	IT Analyst	180	$ 160	180	$ 160
IT Support - Troubleshooting - QC Failur	IT Analyst	30	$ 27	0	$ -
	Radiologist	30	$ 85	0	$ -
QC Oversight	MP	30	$ 52	0	$ -
			$ 732		$ 160

Results

- Total cost of ownership (TCO) was estimated using cash flow:
  - Initial acquisition cost
  - Yearly recurring cost over the expected lifespan (assumed to be 5 years)
- Year one cost for a WCD was $8,881, compared to $11,019 and $17,039 for a WDD with Mid-Level 8MP and High-End 6MP diagnostic-grade displays, respectively
  - Mainly driven by equipment cost
- TCO (5-year) for WCD ($11, 809), exceeded that of a WDD with a Mid-Level diagnostic-grade display ($11,659), but was less than the High-End diagnostic-grade display ($17,678)



Discussion

- Radiology workstations with Commercial-grade displays (WCD) offer significant initial cost savings compared to those with Diagnostic-grade displays (WDD)
- The higher ongoing operational expenses for maintenance and support of WCDs, relative to stations with automated QC, may negate these initial savings over time
- WDD may, therefore, offer long-term financial advantages. In some instances, these advantages may even be achieved within the first 5 years of ownership, over which diagnostic-grade displays will generally be under warranty
- The balance between short-term savings and long-term financial benefits depends on the budgetary needs of the radiology practice